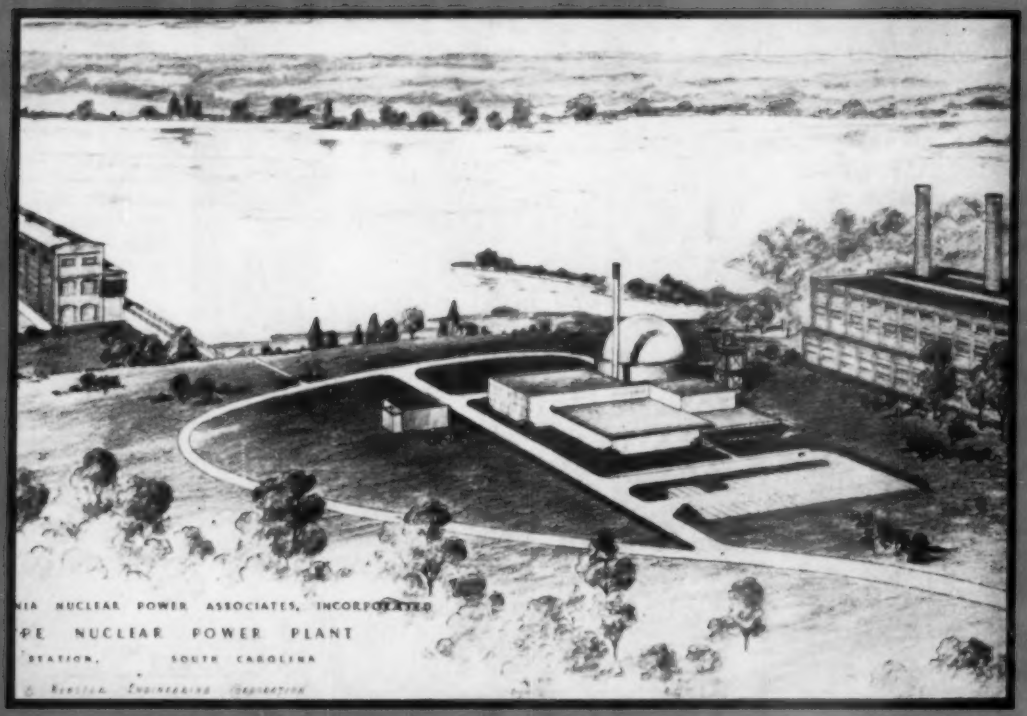
COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

April 1958



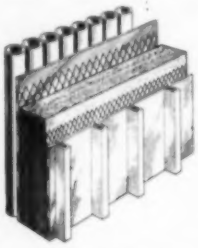
Architect's rendering of the Parr Station, South Carolina, prototype nuclear power plant, of the Carolinas Virginia Nuclear Power Associates, places it between an older hydro plant and an existing conventional station.

Visual Aid to Duct Design

ABC's of Demineralization

Automatic Boiler Operation

American Power Conference—I

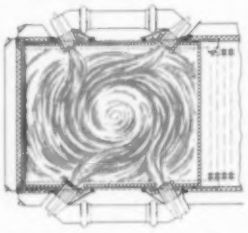


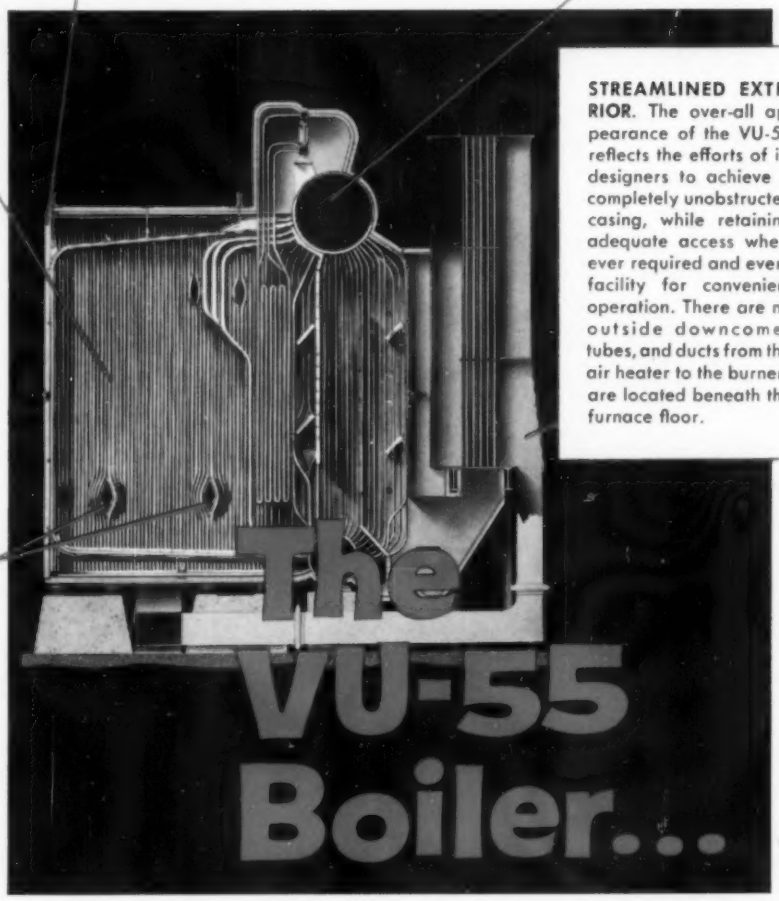
DOUBLE WALL, PRESSURE-TIGHT CASING. The latest development in casing construction for pressure firing of boilers in the size class of the VU-55, this casing is designed to assure life-time tightness with minimum heat loss. Pressure firing permits the elimination of an induced draft fan with its attendant operating and maintenance costs. Construction consists of tangent tubes backed up successively by welded steel panels, 4 inches of high quality insulating material and an outer steel casing formed as shown to provide adequately for expansion and assure ample strength. Low heat loss and the tightness required for pressure firing are assured by this double-wall construction.

HIGH STEAM QUALITY. Equipped with a large (60-in.) steam drum, the VU-55 has generous water capacity and steam reservoir space. C-E drum internals assure high quality steam at all ratings.

TANGENT FURNACE TUBES. The VU-55's furnace tube arrangement provides complete heat-absorbing, water-cooled protection on all furnace walls. Furnace maintenance is minimized, refractory expense is eliminated, heat absorption rates per sq. ft. are higher.

TANGENTIAL FIRING. More than 20 years of application experience have established the exceptional advantages of tangential firing. About 90 per cent of Combustion's large utility installations use this advanced method of firing. Flame streams from the four burners impinge upon one another at high velocity, as shown, creating a turbulence unattainable by any other method of firing. The result is rapid and complete combustion. As the gases spiral upward, they sweep all furnace heating surfaces, assuring a high rate of heat absorption.





STREAMLINED EXTERIOR. The over-all appearance of the VU-55 reflects the efforts of its designers to achieve a completely unobstructed casing, while retaining adequate access wherever required and every facility for convenient operation. There are no outside downcomer tubes, and ducts from the air heater to the burners are located beneath the furnace floor.

The VU-55 Boiler...

Custom Features, Standard Sizes, Advanced Design

The VU-55, newest of the C-E line of Vertical Unit Boilers, represents the closest approach to central station performance yet achieved in standardized boilers in its capacity range.

Its design combines a number of time-tested and service-proved features, such as Tangential Burners, double wall, pressure-tight casing, and tangent furnace tubes. In addition, this bottom-supported unit requires no outside supporting steel, is economical of space and streamlined in appearance.

It is available in 5 sizes for capacities from 50,000 to 120,000 lb per hour. It is designed for 3 pressure ranges (250, 500 and 750 psi) and can be equipped with a superheater to provide temperatures up to 750 F. Either a tubular or a regenerative air heater is available.

The VU-55 Boiler is symmetrical in design, performs efficiently over a wide range of output, and is easy to operate and maintain.

It is, in fact, the boiler with the custom features and the advanced design.

COMBUSTION ENGINEERING

Combustion Engineering Building • 200 Madison Avenue, New York 16, N. Y.

Canada: Combustion Engineering-Superheater Ltd.

B-978A

all types of steam generating, fuel burning and related equipment; nuclear reactors; paper mill equipment; pulverizers; flash drying systems; pressure vessels; soil pipe.

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

Vol. 29 **No. 10**

April 1958

Feature Articles

A Visual Approach to Duct Design for Power Plants ..... *by M. J. Archbold* 34
The ABC's of Demineralizing ..... *by F. N. Kemmer* 41
Automatic Boiler Operation ..... *by K. D. Cilley* 45
The Reduction of the Errors of Coal Sample Preparation ..... *by R.A. Mott* 47
The American Power Conference—I 51
Fourth Nuclear Congress Convenes In Chicago 56

Editorials

An Engineering Heritage Too Long Overlooked 33

Departments

Advertising Index 62, 63

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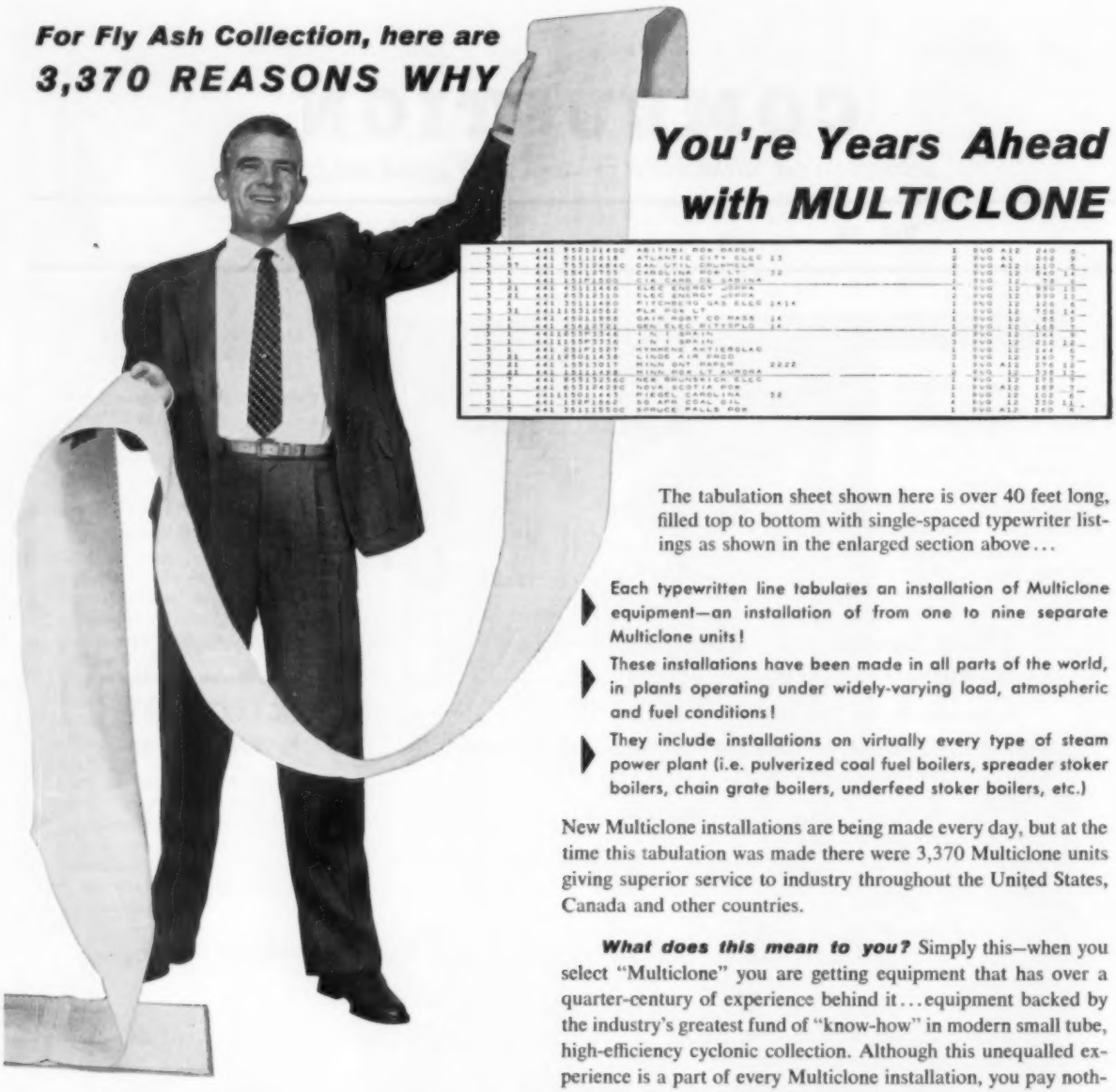
BPA

Printed in U. S. A.

For Fly Ash Collection, here are 3,370 REASONS WHY

You're Years Ahead with MULTICLONE



The tabulation sheet shown here is over 40 feet long, filled top to bottom with single-spaced typewriter listings as shown in the enlarged section above...

- Each typewritten line tabulates an installation of Multiclone equipment—an installation of from one to nine separate Multiclone units!
- These installations have been made in all parts of the world, in plants operating under widely-varying load, atmospheric and fuel conditions!
- They include installations on virtually every type of steam power plant (i.e. pulverized coal fuel boilers, spreader stoker boilers, chain grate boilers, underfeed stoker boilers, etc.)

New Multiclone installations are being made every day, but at the time this tabulation was made there were 3,370 Multiclone units giving superior service to industry throughout the United States, Canada and other countries.

What does this mean to you? Simply this—when you select "Multiclone" you are getting equipment that has over a quarter-century of experience behind it...equipment backed by the industry's greatest fund of "know-how" in modern small tube, high-efficiency cyclonic collection. Although this unequalled experience is a part of every Multiclone installation, you pay nothing extra for this vital advantage!

Send For Descriptive Literature on Multiclone Equipment!

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Engineers and Constructors of Equipment for Collection of Suspended Material from Gases . . . and Equipment for the Process Industries

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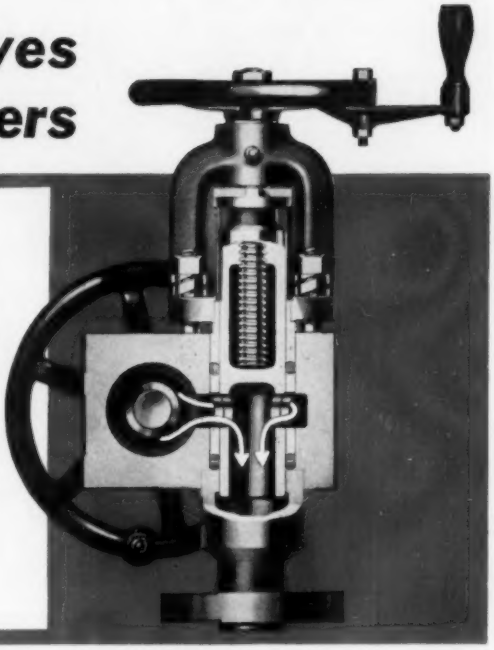
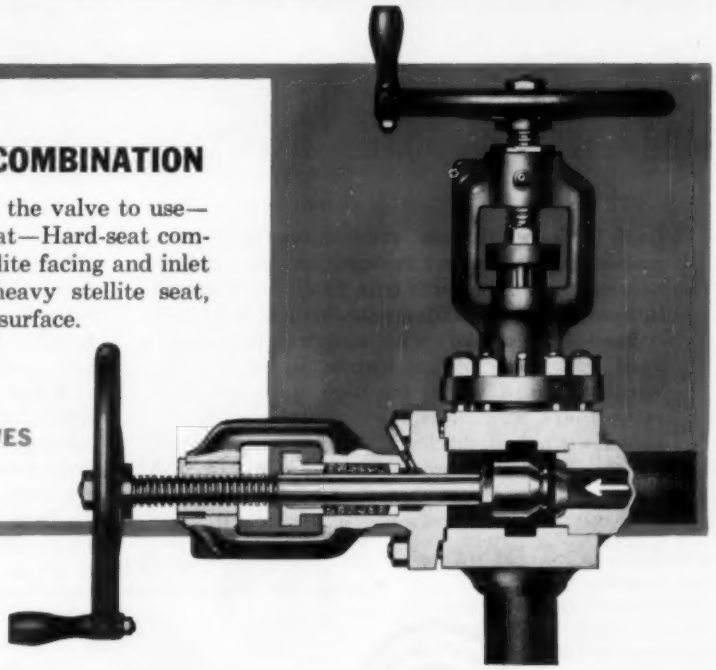
UNIT TANDEM

rugged blow-off valves for high pressure boilers



HARD-SEAT—SEATLESS COMBINATION

■ For boilers up to 1500 psi, this Yarway Unit Tandem Blow-Off Valve offers the maximum in dependable service. A one-piece forged steel block serves as the common body for the Yarway Stellite Hard-seat blowing valve and the Yarway Seatless sealing valve. All interconnecting flanges, bolts and gaskets are eliminated. The Unit Tandem at right is sectioned through Seatless Valve to show balanced sliding plunger in open position and free flow.



HARD-SEAT—HARD-SEAT COMBINATION

■ For boilers to 2500 psi, this is the valve to use—Yarway's Unit Tandem Hard-seat—Hard-seat combination. Disc has welded-in stellite facing and inlet nozzle has integral welded-in heavy stellite seat, providing smooth, hard-wearing surface.

OVER 4 OUT OF 5
HIGH PRESSURE PLANTS
USE YARWAY BLOW-OFF VALVES

Write for Yarway Catalog B-43¼

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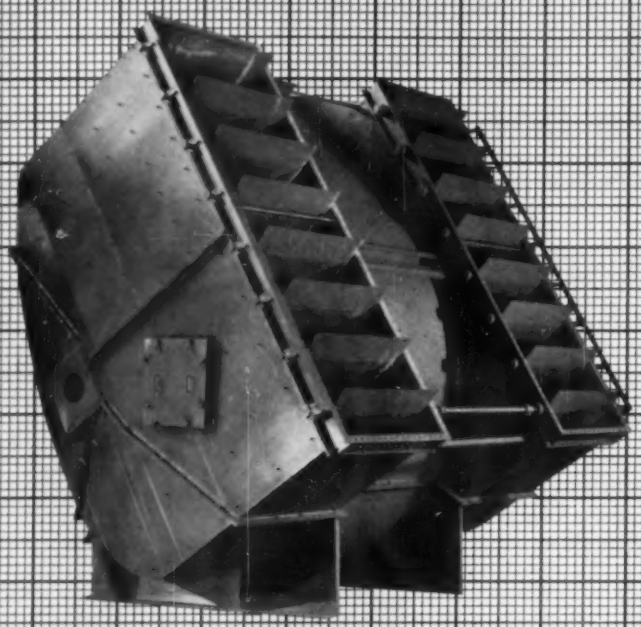
YARWAY **BLOW-OFF VALVES**

AMERICAN BLOWER SIROCCO FANS



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LOW INITIAL COST
SMALL FLOOR SPACE

LOW RPM • LONGER LIFE
LOW WR²

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Look for low initial cost, reduced operating costs, guaranteed performance ratings, minimum maintenance and space requirements. You'll find them *all* in American Blower Sirocco mechanical draft fans.

Specially designed for induced-draft and forced-draft work, Sirocco Fans feature die-formed, forwardly inclined blades for high static efficiency at low rpm's. Streamline, low-turbulence inlets also contribute to high efficiency. And for longer service life, Sirocco Fans have heavy-duty rim and hub plate construction . . . heavy, steel-plate housings and inlets. Special erosion-resistant features are available, as well.

For high efficiency, low cost over the entire operating range, couple Sirocco Fans with American Blower *Gyrol*® Fluid Drive. Infinitely variable in speed, Gyrol Fluid Drive matches fan speed to boiler demand; pays off in longer life for fan wheels and bearings; quieter operation.

If you are investigating mechanical-draft equipment for new or existing installations, take advantage of our experience in air handling. Call your nearby American Blower branch office, today. Or write: American-Standard,* American Blower Division, Detroit 32, Michigan. In Canada: Canadian Sirocco products, Windsor, Ontario.

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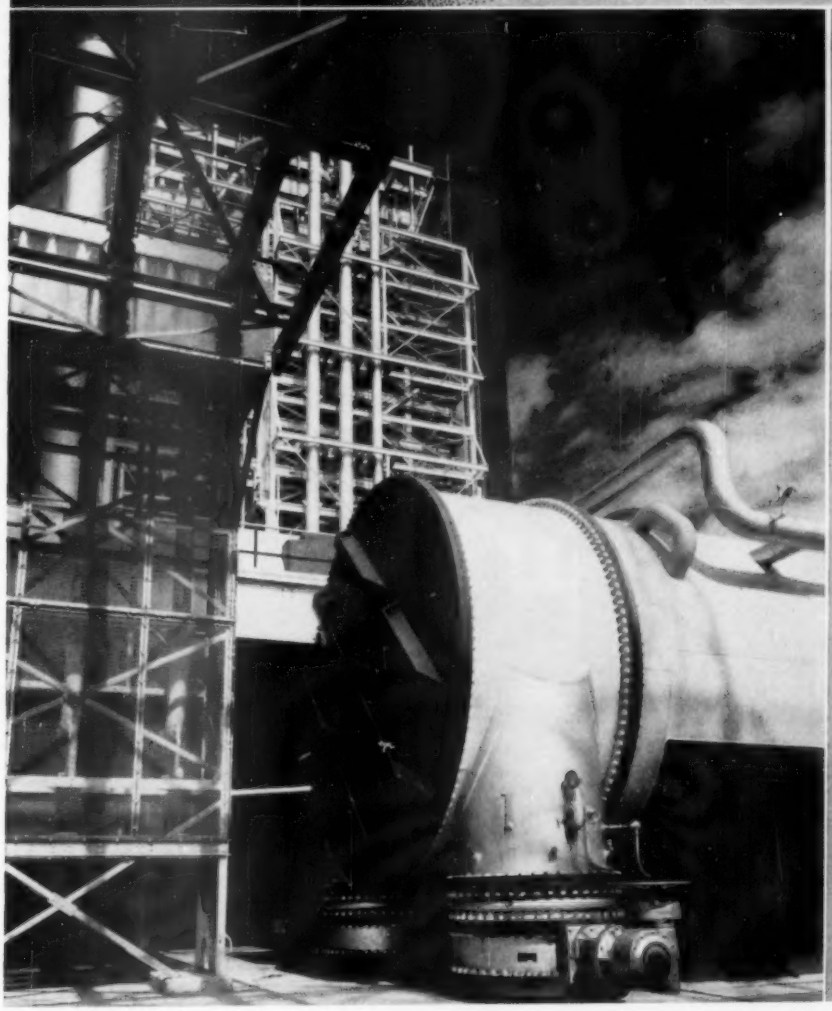
PROGRESS IN POWER through PROGRESS IN HEAT TRANSFER EQUIPMENT



LARGE CONDENSERS PRODUCED BY YUBA DESIGN ABILITY

Consulting Engineers—Ebasco Services Inc.

As the demand for larger turbines continues, Yuba keeps step with progress by furnishing surface condensers of ever increasing size and efficiency.

Here is one of two 45,000 sq. ft. condenser sections designed and built for the Collin Generating Station of the Texas Power & Light Co. The two sections connected to a single turbine exhaust by a T-piece have a total surface of 90,000 sq. ft.

Yuba has designed and built condensers with 165,000 sq. ft. of surface. The designs of these large condensers can be adapted to condensers of even greater capacity as required for larger turbines.

In the design of surface condensers, Yuba incorporates such features as low-pressure heaters and complete de-aeration facilities within the condenser shells, thereby saving costly plant space and piping.

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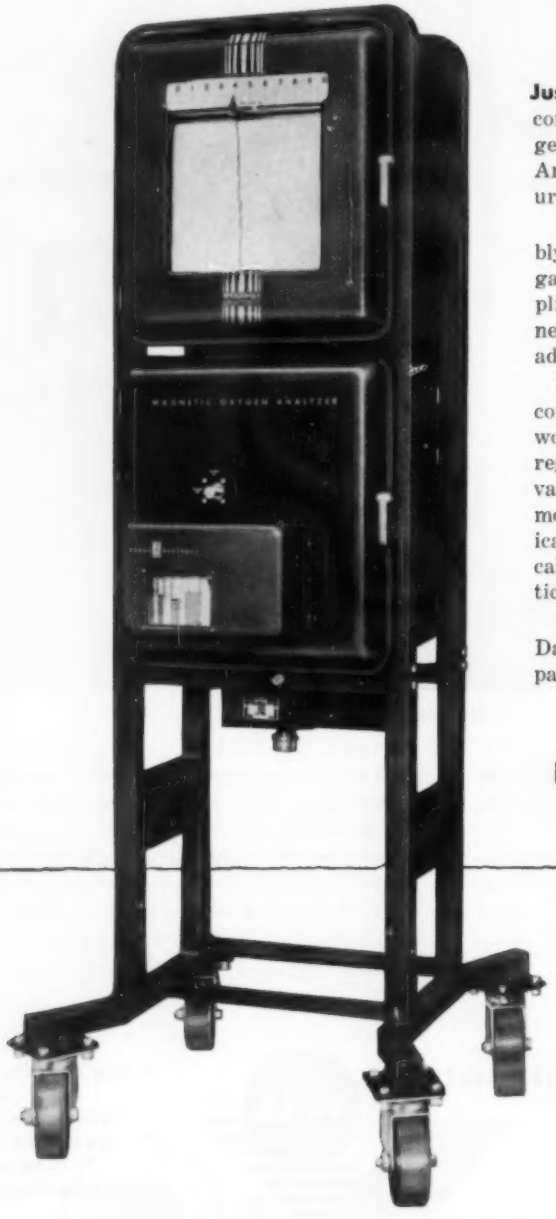
YUBA CONSOLIDATED INDUSTRIES, INC.

GET O_2 DATA...

with new flue gas analyzer

ANYWHERE...ANY TIME...



Just roll this Magnetic O_2 Analyzer Recorder up to any sample pick-off point and get continuously recorded excess air data. And it's accurate data, for complete measurement is by direct magnetic action.

Already, operators are using the assembly for many purposes . . . checking flue gas stratification, verifying regular sampling points, exploring the suitability of new sampling points, checking for burner adjustment.

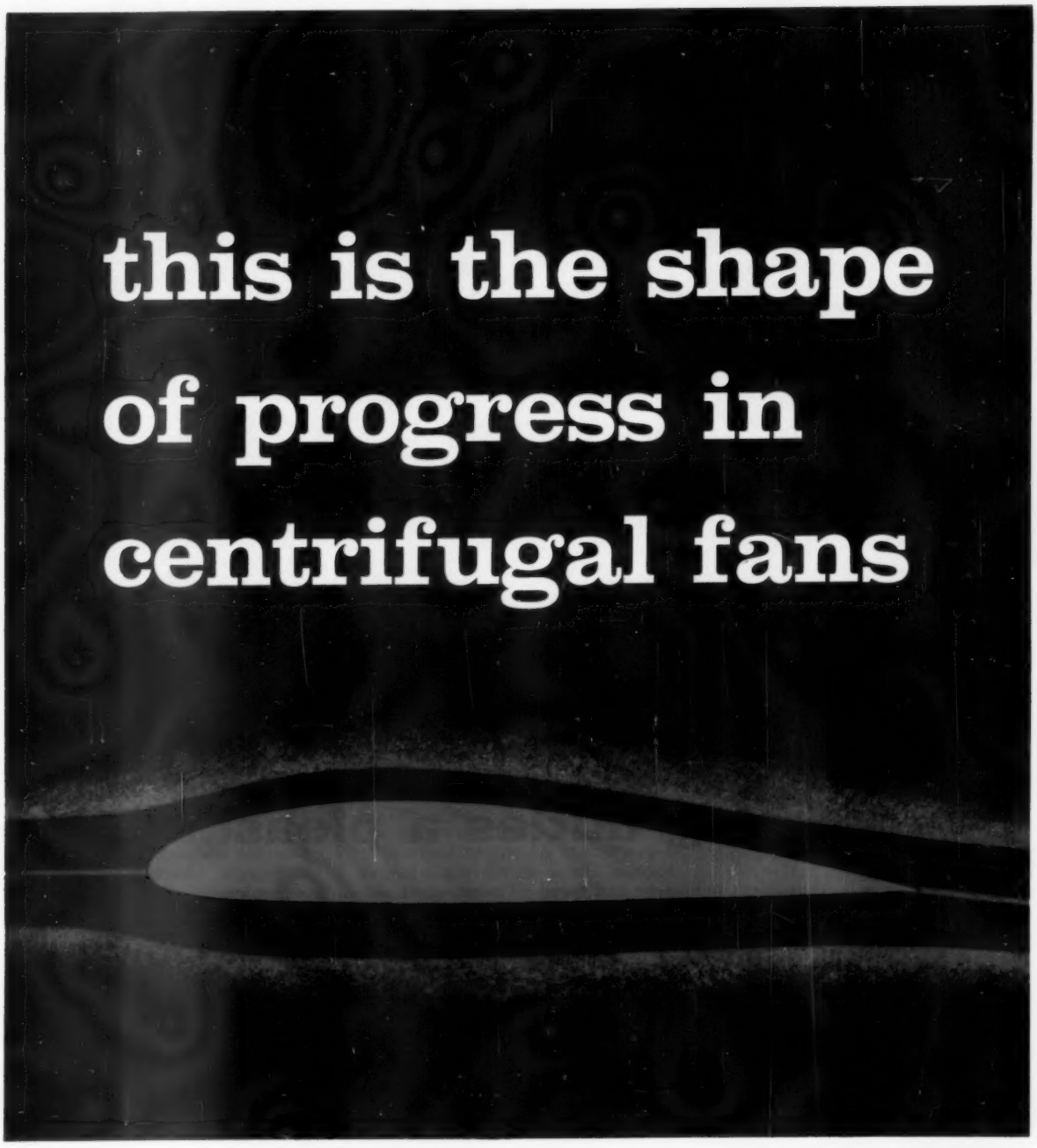
This rugged assembly is designed for continuous day-after-day operation . . . works from any 115-volt, 60 cycle non-regulated power source . . . has its own vacuum pump and sample cleaning filters mounted on the rear . . . doesn't need chemical reactions or auxiliary gas supplies for calibration and operation . . . requires practically no set-up time.

For more details write for Preliminary Data Sheet 463-61. Leeds & Northrup Company, 4972 Stenton Ave., Phila. 44, Pa.

LEEDS NORTHRUP
Instruments Automatic Controls • Furnaces

PERFORMANCE

Range	0 to 5% O_2, 0 to 10% O_2, or higher in flue gas as specified
Accuracy	0.15% O_2
Sensitivity	Better than ±0.05% O_2
Stability	Better than ±0.15% O_2
Response	Initial response at Analyzer, 4 sec.; to 90% of full scale at Analyzer, 30 sec. Typical sampling lag, 1 sec. per 6 ft. of ¼" plastic tubing



Westinghouse Airfoil Blading, the last word in centrifugal fan design, provides efficiency and quietness in mechanical draft applications.

With these advantages:

- Quiet Operation
- Lowest Operating Costs
- Stable Pressure
- Non-Overloading Feature

Available with Airfoil Blading:

Primary Air Fans
up to 40,000 cfm . . . . . up to 65″ pressure
Combustion Air Fans (High-Pressure Forced-Draft)
up to 350,000 cfm . . . . . up to 90″ pressure
Combustion Air Fans (Standard Mechanical Draft)
up to 700,000 cfm . . . . . up to 40″ pressure

More Information?

Call your nearest Sturtevant Division Sales Engineer or write Westinghouse Electric Corporation, Dept. D-17, Hyde Park, Boston 36, Massachusetts.

J-80667

Bailey Meters and Controls for Combustion, Feed Water, Steam Temperature and Condensate at Moores Park Station, City of Lansing, Michigan.

How Bailey makes steam operating duties a pleasure—

Fingertip Controls, convenient indicators and trend recorders make steam control room operating duties a pleasure. You get this bonus for your operators when you specify Bailey Meters and Controls.

Bailey is the choice of virtually all the most efficient plants on the Federal Power Commission's heat rate report. Here's why:

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You can be sure a Bailey Engineer will offer the right combination of equipment to fit your needs.

Bailey manufactures a complete line of standard, compatible pneumatic and electric metering and control equipment that has proved itself. Thousands of successful installations involving problems in measurement, combustion, and automatic control are your assurance of the best possible system.

2. Experience

Bailey Engineers have been making steam plants work more efficiently for more than forty years. Veteran engineer and young engineer alike, the men who represent Bailey, are storehouses of knowledge on measurement and control. They are up-to-the-minute on the latest developments that can be applied to your problem.

3. Sales and Service Convenient to You

There's a Bailey District Office or Resident Engineer close to you. Check your phone book for expert engineering counsel on your steam plant control problems.

A133-1

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Instruments and controls for power and process

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Hall Industrial Water Report

VOLUME 6 APRIL 1958 NUMBER 2

Steam-Electric Power Plants Have to Keep Rolling

If they don't, our whole complex machinery of civilization suddenly dies. Mills go down, office buildings go dark, air conditioning stops—even television is blinded.

Undisciplined water can cause unscheduled outages. That is why upwards of 300 utilities and more than 2500 industrial steam generating plants retain Hall Laboratories to help them avoid water problems and to solve them when they do occur. This is a most important part of Hall's activities on all kinds of industrial water—cooling water, service water, process water, waste water.

Disappearing Phosphate

One summer the operators in a Midwestern utility plant were puzzled by the disappearance of boiler water phosphate residuals over a number of consecutive week ends. Then to their dismay, boiler tubes began to fail as a result of scale formation.

It was obvious to Hall Engineer J. F. Nelson that the boiler feedwater was being contaminated with hard water over week ends, but finding the point of contamination proved difficult. Innumerable samples of feedwater drawn hourly by the operators showed only the usual 0.5 ppm or less of hardness. However, one night when the air conditioning load dropped abnormally because of cooler weather, hardness showed up. It was traced to a small boiler feed pump used only for light loads. Hard water used for sealing was leaking into the pump suction when load was sufficient to reduce the pressure below that of the sealing water.

Diagnosis had been difficult because contamination occurred only with the small pump used when loads were light and only when this pump was operated at full capacity. These conditions were experienced mainly over week ends.

As with most problems, correction was easy once a satisfactory diagnosis had been made. Substitution of condensate for hard water as gland sealing water eliminated the contamination regardless of load.

An Opportune Visit

On a routine visit to a western utility plant Hall Engineer C. L. Fitzgerald found management trying to decide what to do about preparation of makeup water for a new steam-electric unit. The inclination was to use existing evaporators because of a $100,000 price tag on demineralizing equipment. How to pretreat evaporator feedwater was the pressing problem.

The existing pretreating equipment consisted of an old lime-soda plant operated batchwise in the cold. Consideration was being given to costly, extensive repair work on the old plant and to installation of individual chemical feed tanks and proportioning pumps for the evaporators. Fitzgerald agreed that the changes contemplated would facilitate water treatment and improve evaporator feedwater conditions and vapor quality. However, he was quick to propose an alternative which would involve lower capital investment and operating cost.

Fitzgerald's recommendation was to scrap the existing equipment and to replace it with sodium zeolite softeners costing approximately $2000. Two existing tanks could be used for storage of softened water and one chemical tank and proportioning pump would suffice to feed chemicals into the water line to the evaporator preheater. This arrangement would not only produce excellent quality water for the evaporators but it would do so with a minimum of attention and at low cost.

The scheme proposed was not hard to sell to management. Capital expenditure dropped by stages from the first considered $100,000 to a final figure of close to $2000. The daily saving in chemical cost was sufficient to amortize the expenditure in little more than one year.

Why So Much Copper

When a routine analysis disclosed the presence of an unusually high concentration of copper in the recirculating cooling water at a midwestern city light plant, the operators were justifiably alarmed. That the copper was accelerating corrosion of steel was indicated by a steel test strip removed from the cooling water system. Along with severe pitting, the strip showed copper plating.

No copper compound was being used as an algaecide. Furthermore, routine checks showed the pH value of the circulating water to be 8.0, high enough to control corrosion of copper alloy condenser tubes.

Hall Engineer W. E. Pfeiffer reasoned that the copper source had to be the condenser tubes. Perhaps pH control was not really as good as indicated. Upon investigation, he found that the operators, to facilitate acid feeding, had changed the point of application and were feeding intermittently at hourly intervals. Further determinations revealed that while the pH value of the circulating water at the condenser outlet was 8.0 when acid feed was started, during the short period of acid introduction it dropped to 3.0.

With the problem in focus, changes were made to feed acid properly and thus return to normal the copper content of the water and the operator's peace of mind.

Industrial Water Problems Require Special Handling

There are no "stock answers" to industrial water problems. For information on how the Hall System can help you solve your particular water problems, write, wire or call address below.

Water is your industry's most important raw material. Use it wisely.

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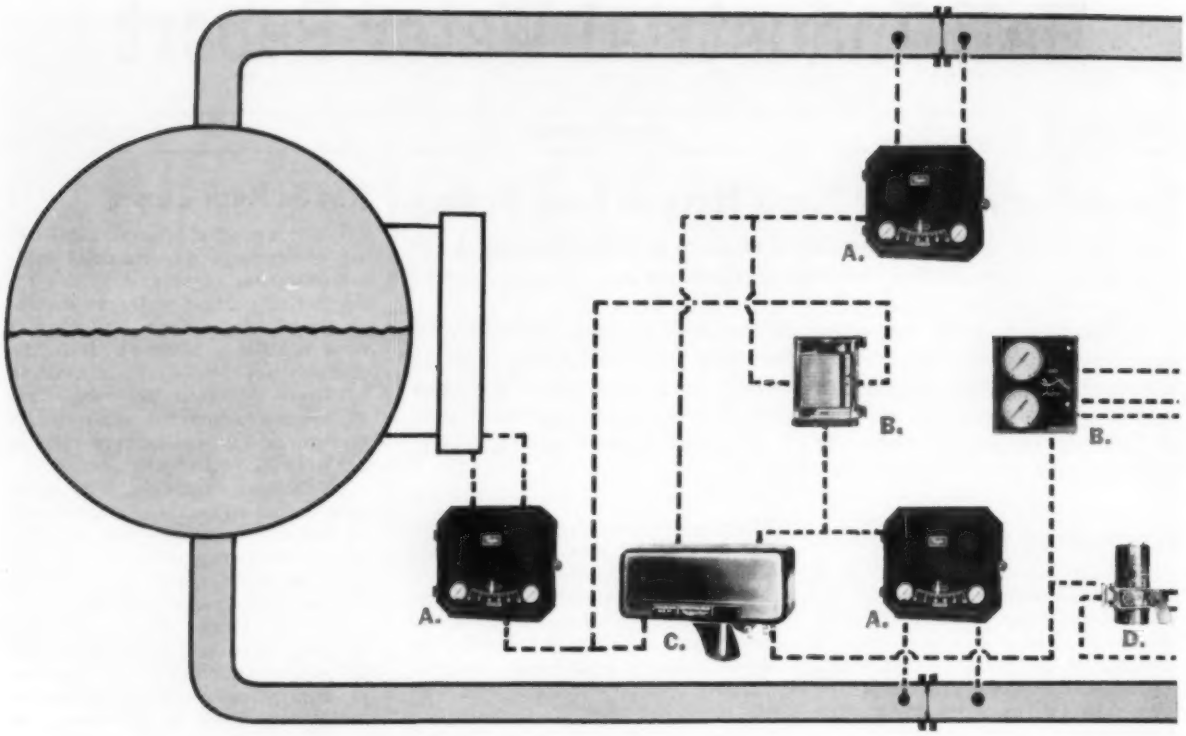
DIVISION OF HAGAN CHEMICALS & CONTROLS, INC.
HAGAN BUILDING, PITTSBURGH 30, PENNSYLVANIA
DIVISIONS: CALGON COMPANY, HALL LABORATORIES
IN CANADA: HAGAN CORPORATION (CANADA) LIMITED, TORONTO

Hall Laboratories—Consultants on Procurement, Treatment, Use and Disposal of Industrial Water



Copes Feedwater Control brings stability to high-duty steam generators

Today's modern boiler design with higher ratings and fast load changes requires increased accuracy and more sensitive response in regulating water feed into the steaming boiler.

To meet these rigid demands, Copes Type 3-L Feedwater Control combines the dynamic balance of custom-engineered control valves with the positive performance of precision-built instruments.

Feed to the boiler is modulated by three influences—steam flow, feedwater flow and drum water level. Feedwater input closely matches steam output on constant loads or during periods of wide load changes. A stabilized water level is always maintained regardless of changes in load or feed pressure, and while blowing down or blowing soot.

Space-saving instruments record steam flow, feedwater flow and water level on linear strip charts. These charts give a 30-day continuous record, with a 3-hour record clearly visible. Standard-size recorders are also available.

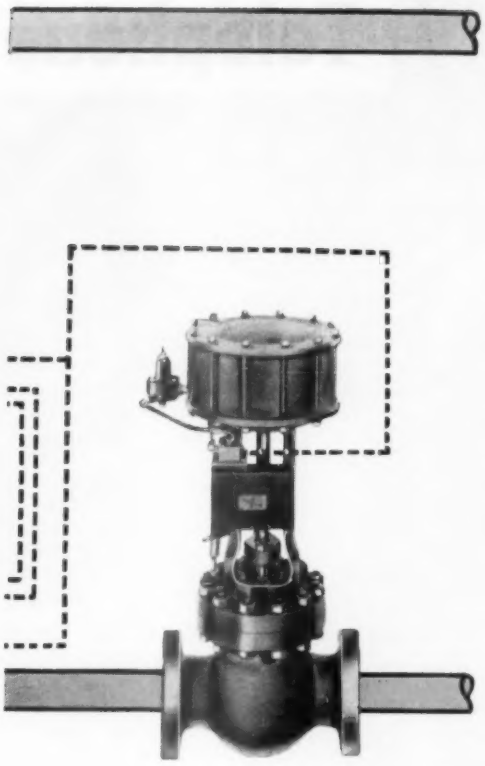
A complete line . . . a complete service

Over 50 years of design experience backs Copes-Vulcan's broad line of control systems for boiler cleaning, combustion, feedwater, pressure reducing and desuperheating operations.

Bulletin 1038 shows feedwater control at Seward Station

This twelve-page bulletin details Seward's complete control system. Schematic drawings show air flow and fuel loading loops. Boiler drawings locate Vulcan soot blowers and wall deslaggers. Write for your copy.

Copes-Vulcan Division
BLAW-KNOX COMPANY
Erie, Pennsylvania



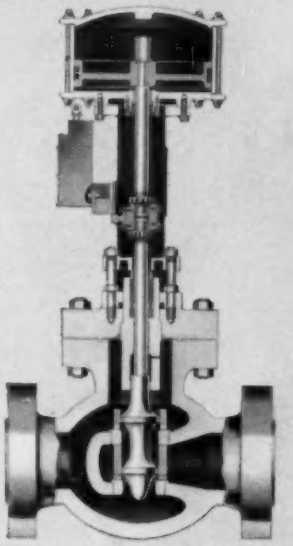
A. Indicating transmitters send water level and flow influences to the computing relay where steam-flow and water-flow are accurately balanced and water-level influence is relayed by air impulse.

B. Miniature recorders and transfer panel are ideal for console-type or graphic panels or for compact grouping on existing panels. Conventional recorders of standard size are also available.

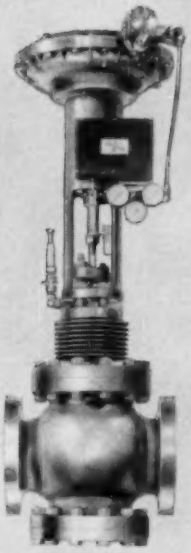
C. Compact beam-balanced type computing relay sends an air impulse to the controller and auto-manual transfer panel, either of which can closely control the feedwater valve position.

D. Transet controller has been designed to provide two-knob turning. Controller, transmitters and relays may be field mounted wherever most convenient without respect to location to each other.

C-V NEWS NOTES



Type CV-P Valve



Type CV-D Valve

Maximum power with precise positioning is assured with Copes-Vulcan Type CV-P Valve. Responsive to most minute changes in actuating impulse, this rugged valve delivers top power at the valve stem. For less demanding service conditions, Copes-Vulcan builds a versatile diaphragm-operated Type CV-D Valve.

Bevel-seated cylinder type
Rectangular ports Characterized V ports

Stream-flow type
Bevel-seated

The right fitting for the job. Copes-Vulcan valves are furnished for all capacities and pressures with closely balanced bevel-seated plunger and seats of stainless steel with stellite facing when required. Ports are job-engineered according to specified flow and pressure conditions. Wear on moving parts is minimized.

Telephone

manufacturer calls for coal

Automatic Electric Co. burns coal in new plant because of cost and availability

Modern facilities, modern products, modern fuel—you'll find all three at the new Northlake, Ill., plant of Automatic Electric Co., manufacturing subsidiary of General Telephone. The power house of this communications equipment plant (designed and built by The Austin Company of Cleveland) is as modern and efficient as the manufacturing process itself. The plant required large quantities of economically and reliably produced steam for process work and heating. The fuel selected was *coal*, because of coal's economy and abundant supply. As a result, today Automatic Electric enjoys dependable, low-cost steam.

Facts you should know about coal

You'll find that bituminous coal is not only the lowest-cost fuel in most industrial areas, as in the case of Automatic Electric, but up-to-date coal burning equipment can give you 15% to 50% more steam per dollar. Today's automatic equipment can pare labor costs and eliminate smoke problems. And vast coal reserves plus mechanized production methods mean a constantly plentiful supply of coal at stable prices.

Technical advisory service

To help you with industrial fuel problems, the Bituminous Coal Institute offers a free technical advisory service. We welcome the opportunity to work with you, your consulting engineers and architects. If you are concerned with steam costs, write to the address below. Or send the coupon below for case histories, complete with data sheets. You'll find them informative.

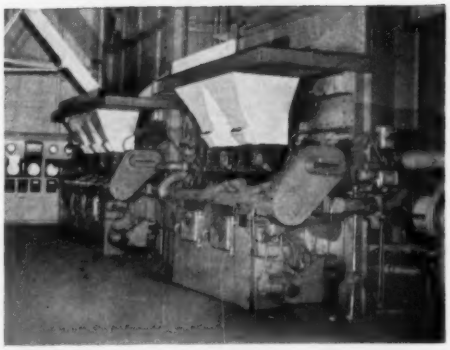
Consult an engineering firm

If you are remodeling or building new heating or power facilities, it will pay you to consult a qualified engineering firm. Such concerns—familiar with the latest in fuel costs and equipment—can effect great savings for you in efficiency and fuel economy over the years.

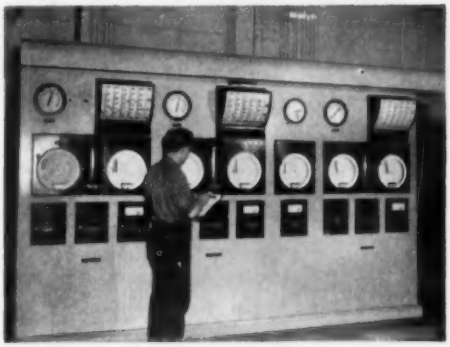
BITUMINOUS COAL INSTITUTE

Department C-04

Southern Building • Washington 5, D.C.



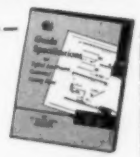
Shown are two of the three Keeler boilers – fired by Detroit Spreader Stokers – in the power plant. At the right is the 22,000 lb/hr boiler. In the background is one of the 50,000 lb/hr boilers. The two sizes allow flexibility in operation for widely varying load requirements.



Control panel by Hays Corporation. This system regulates all operations of the boilers—steam pressure, draft, flue gas temperature, banking periods, etc. —to give complete, automatic control of steam generating operation.

Ash disposal system, by United Conveyor Co., in basement of boiler room. Ash is removed from furnace by Detroit CC grate, drops into hoppers in basement and is taken by vacuum to silo.

The Bituminous Coal Institute now has available a free booklet adaptable for design loads 3,000 to 24,000 EDR steam. This booklet, "Guide Specifications for Typical Low-Pressure Commercial Heating Plant," contains specifications, drawings and tables on all aspects of a typical heating plant. Send in this coupon for your copy.



☐ Guide Specifications Booklet ☐ Case histories on larger plants.

CC-4

Name_____

Title_____

Company_____

Address_____

City_____ Zone____ State_____

More power to you !

There are wide differences in coal; wide differences in plant equipment and operation. When the two are matched, they team up to "knock down" steam generating costs.

This match-making can best be accomplished with the help of Norfolk and Western coal consultants. Tell these men about your operation, and they will recommend a *Fuel Satisfaction** coal "tailored" to your needs.

From seam to steam, every precaution is taken in the production, processing and transportation of *Fuel Satisfaction* coals to assure a product of the highest quality and uniformity. Every load of this superior Bituminous Coal can mean . . . *more power to you!*

**Fuel Satisfaction* is the name given the many fine brands of superior all-purpose Bituminous Coal mined along the N&W.

Norfolk and Western RAILWAY

CARRIER OF FUEL SATISFACTION

For technical advice and assistance on utilization problems, consult with N&W fuel specialists. There's no obligation.

ROANOKE
N&W Coal Traffic Dept.
Telephone Diamond 4-1451, Ext. 313, 423, 249, 732
Roanoke, Virginia

BOSTON
833 Chamber of Commerce Building
Telephone Liberty 2-2229
Boston 10, Massachusetts

CHICAGO
Room 604, 208 South LaSalle Street
Telephone RAndolph 6-4634
Chicago 4, Illinois

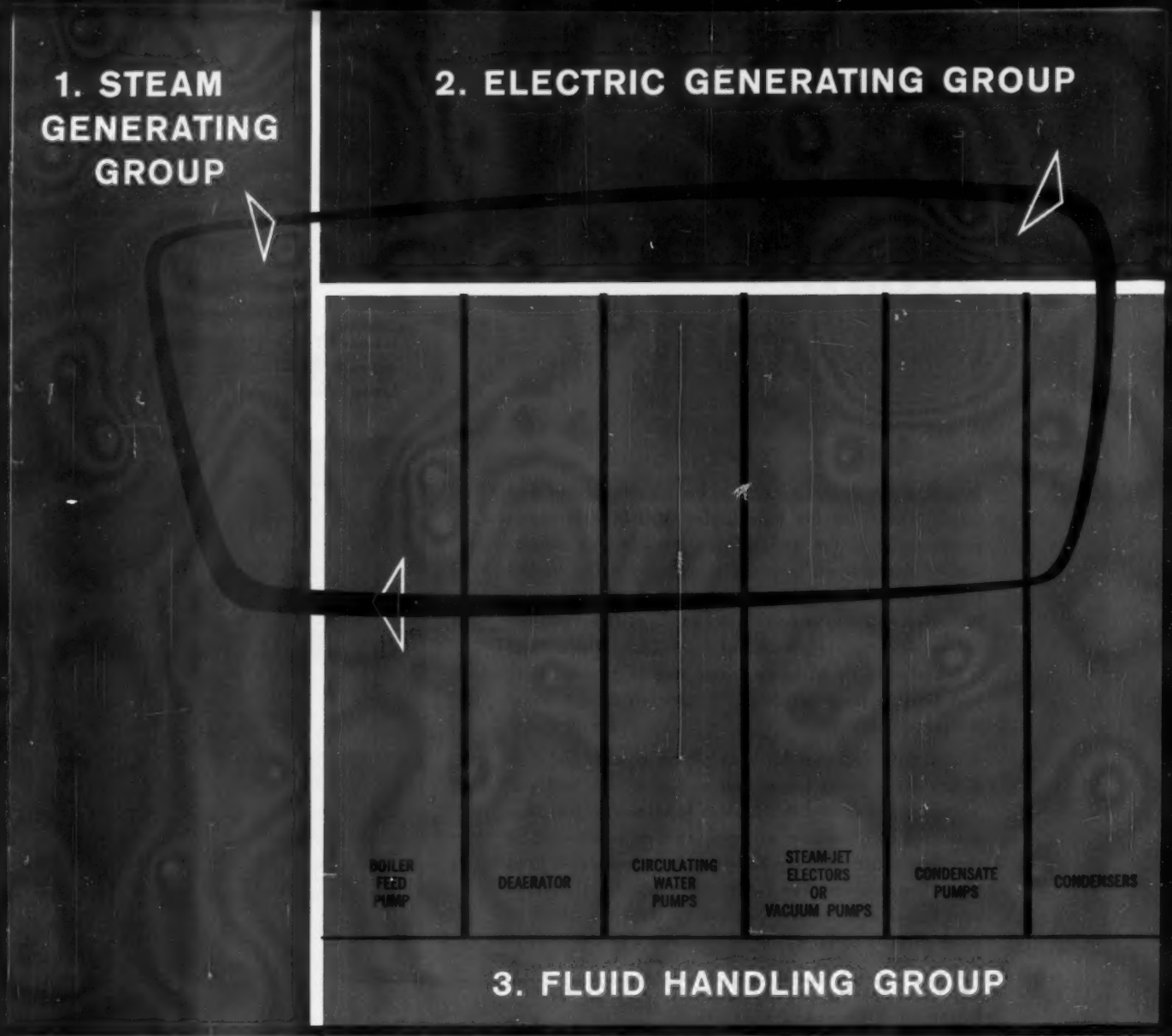
CINCINNATI
913 Dixie Terminal Building
Telephone DUnbar 1-1325
Cincinnati 2, Ohio

CLEVELAND
Room 722, The Illuminating Building
Telephone MAin 1-7960
Cleveland 13, Ohio

DETROIT
1907 Book Building
Telephone WOodward 1-2340 or 1-2341
Detroit 26, Michigan

ST. LOUIS
2059 Railway Exchange Building
Telephone MAin 1-1180
St. Louis 1, Missouri

WINSTON-SALEM
1105 Reynolds Building
Telephone PArk 2-7116
Winston-Salem 1, North Carolina



LOOK AT ALL THREE FOR POWER

THE FLUID HANDLING GROUP in a steam power plant has as many individual components as the other two combined. Failure of any one component can disrupt operation of the whole. Reliability can best be achieved through compatible integration of the wide range of equipment in this all-important group. As a manufacturer of all major fluid handling components, Worthington's "system-wise" experience and knowledge can be of extreme value to you. For information, write or call your nearest Worthington district office. Worthington Corporation, Harrison, New Jersey.

49-1

WORTHINGTON

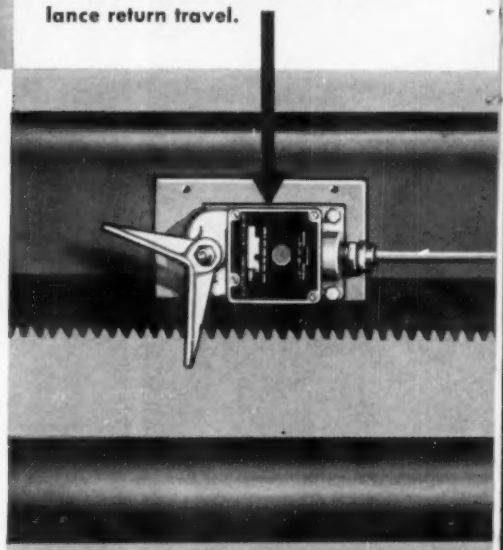
ELECTRIC POWER and CONTROL TERMINAL FACILITIES

ANOTHER

Simple, convenient, rugged . . . the electric power and control center of the new Series 300 IK contributes substantially to the dependable, trouble-free operation of this blower. Terminal facilities and the control assembly are concentrated in a cast aluminum box at the drive end. No internal field wiring is required; the blower is completely wired at the factory. The control is linked directly to lance travel and is governed by two durable snap switches . . . actuated by a cam on the lance carriage.

Additional important features of the new Series 300 IK are listed in the panel below. Check them and you will understand why this blower is establishing a new standard of efficiency, economy and dependability in cleaning those heating surfaces that require a long retracting blower. For further information about the new Series 300 IK, ask the nearest Diamond office or write directly to Lancaster for Bulletin 2111V.

Inboard Travel Limit Switch (cover removed). Switch near other end limits lance return travel.



Control for air operation is also simple, compact, accessible and dependable.

Other Advantages of Series 300 IK Blowers

- Backbone and Protective Cover
- Front End Single-Motor Drive
- Nozzle-Sweep-Every-Inch Cleaning Pattern
- Improved "Type A" Nozzle
- Positive Gear Carriage Drive
- Poppet Valve with Adjustable Pressure Control
- Positive Mechanically Operated Valve
- Single Point Outboard Suspension
- Oversize Lance (Step-Tapered for Extra Long Travel)
- Auxiliary Carriages for Extra Long Travel
- Designed for Quick, Easy Servicing

No other Blower gives you ALL THESE ADVANTAGES

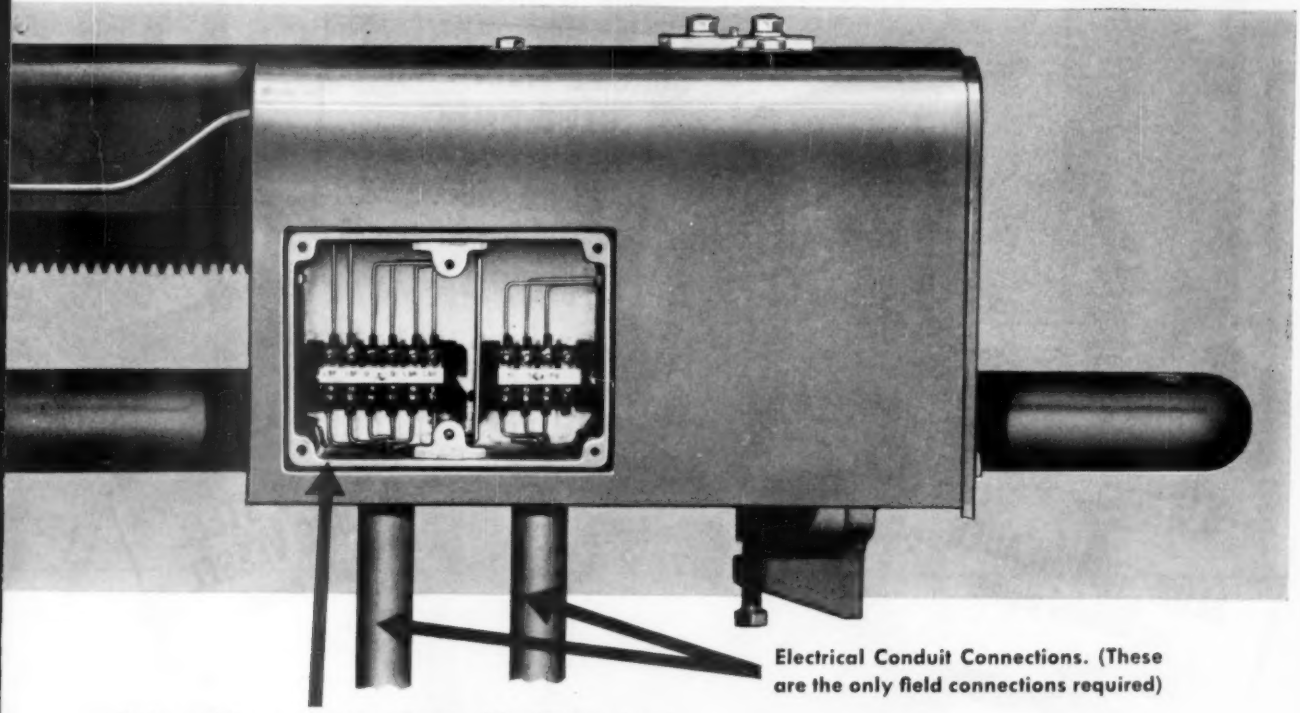
Diamond

DIAMOND POWER

IMPORTANT FEATURE

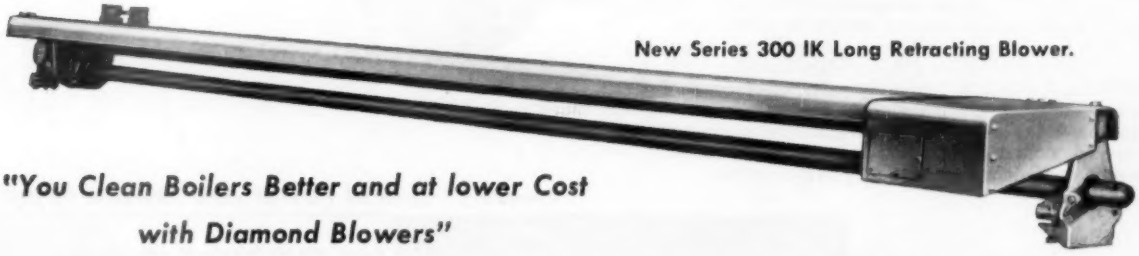
of the new Diamond series 300 IK

LONG RETRACTING BLOWER



Electrical Conduit Connections. (These are the only field connections required)

Motor and Control Electrical Terminal Facilities centered in weather-resistant enclosure at drive end for improved accessibility and protection. (cover removed)



New Series 300 IK Long Retracting Blower.

"You Clean Boilers Better and at lower Cost with Diamond Blowers"

7703

SPECIALTY CORP. **LANCASTER, OHIO**

Diamond Specialty Limited • Windsor, Ontario

ALL IN A DAY'S WORK at *Pittsburgh Piping*

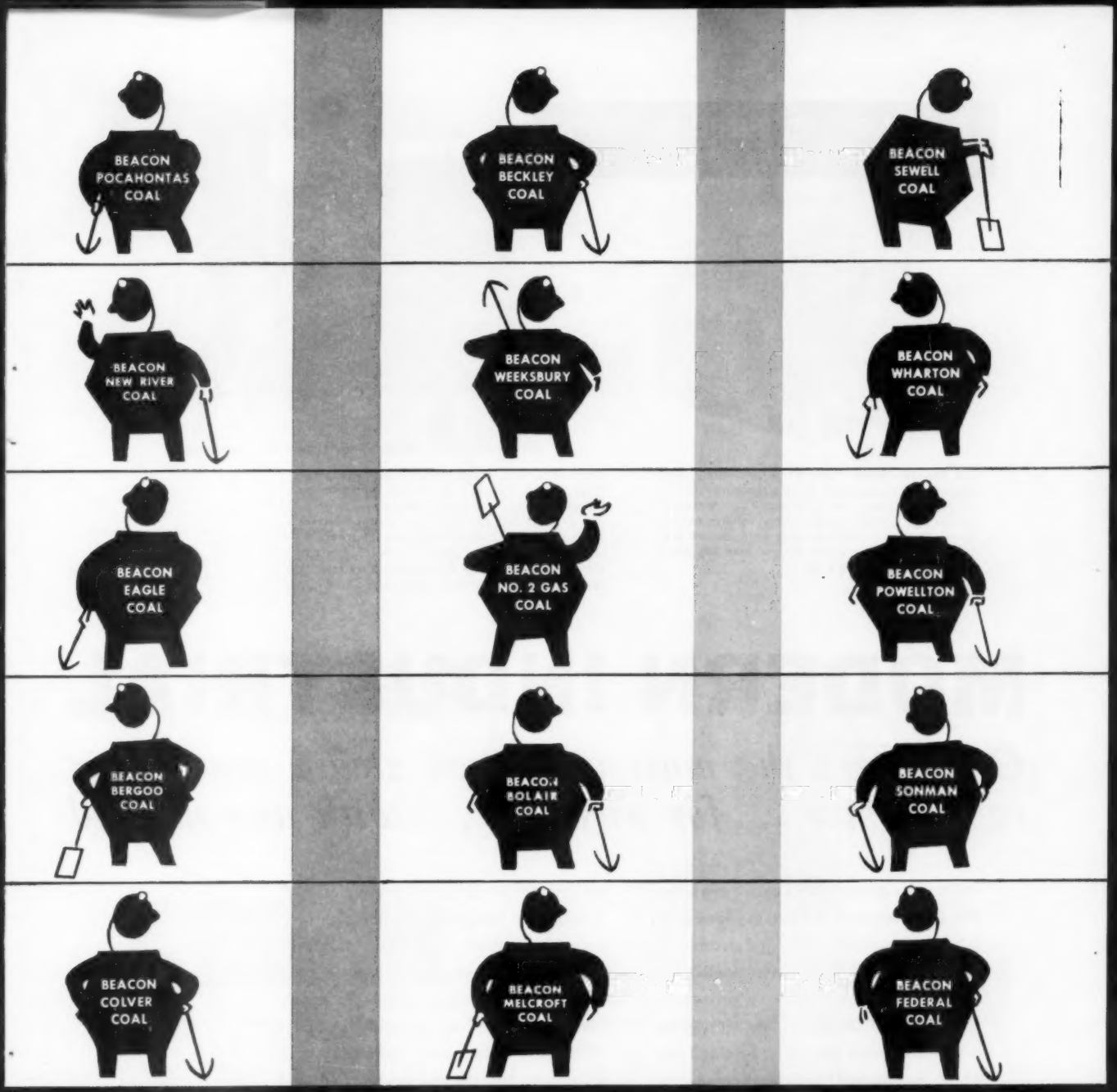
These three jobs are typical of the wide variety of custom piping work which we do for the power and process industries. In the background of the photo welders are shown making the heli-arc root pass on 18" O.D., 3.875" wall, chrome-moly main steam piping. In the foreground, ready for final inspection, is a 12" header for a process operation, fabricated of 3/8" aluminum alloy. The pressure vessel, of austenitic steel, is one of many we produce for atomic energy application. The manufacturing of this type of piping requires specialized facilities . . . for engineering, fabricating, testing, assembly, and erection. We have those facilities. Use them on your piping jobs.

Promoting Progress **IN POWER AND PROCESS PIPING**

Pittsburgh Piping **AND EQUIPMENT COMPANY**
158 49th Street—Pittsburgh, Pa.

Canada: **CANADIAN PITTSBURGH PIPING, LTD.,** 68 YONGE STREET, TORONTO, ONTARIO

Atlanta . . . . . *Whitehead Building*
Chicago . . . . . *Peoples Gas Building*
New York . . . . . *Woolworth Building*
Cleveland . . . . . *Public Square Building*
New Orleans . . . . . *P. O. Box 74*



All squared away to serve you—

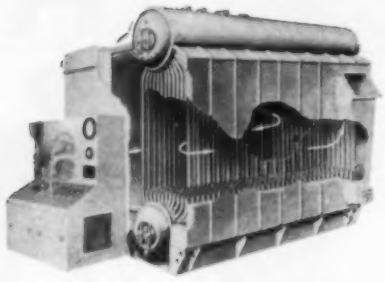
EASTERN GAS AND FUEL ASSOCIATES
BEACON COAL

EASTERN GAS AND FUEL ASSOCIATES

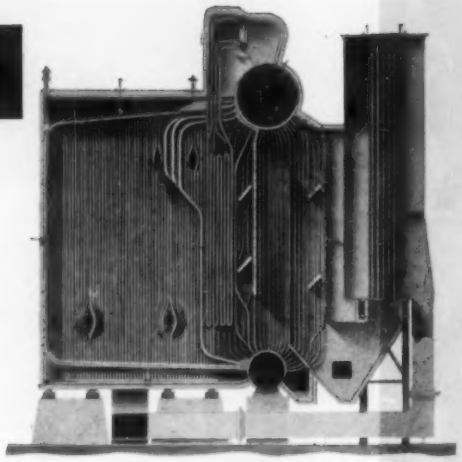
PITTSBURGH • BOSTON • CLEVELAND • DETROIT • NEW YORK
NORFOLK • PHILADELPHIA • SYRACUSE

For New England: New England Coal & Coke Co. • For Export: Castner, Curran & Bullitt, Inc.

OIL AND GAS FIRED BOILERS
(standardized designs)



C-E Package Boiler, Type VP — Completely shop assembled . . . available in 14 sizes from 4,000 to 50,000 lb of steam per hr capacity . . . pressures to 500 psi. Available with integral console control panel. This unit contains more water-cooled area per cubic foot of furnace volume than any other boiler of its size and type.



C-E Vertical-Unit Boiler, Type VU-55 — Available in six sizes . . . capacities from 50,000 to 120,000 lb of steam per hour . . . designed for two pressure ranges, 250 psi and 500 psi, and total steam temperatures up to 750 F. Equipped with tangential burners. 60-inch steam drum assures generous water capacity and steam reservoir space. Tangent tube waterwalls offer complete furnace protection, minimizing maintenance.

MODERN INDUSTRIAL

C-E offers the most advanced steam generating in any size . . . for any fuel . . . with any method

All the designs pictured here have something in common. All are evolved from a basic design concept — a 2-drum, vertical boiler with fully water-cooled furnace in front of the boiler proper — a design which Combustion Engineering originated more than 30 years ago and which has enjoyed the widest acceptance.

All are fully integrated designs comprising boiler, furnace, fuel-burning and, where required, superheat and heat-recovery equipment, coordinated into a smoothly functioning unit.

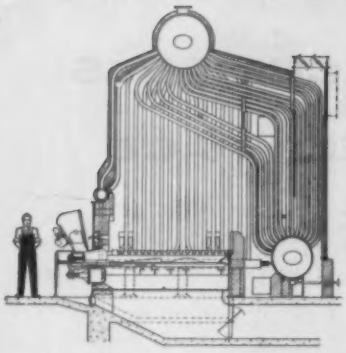
All have benefited from C-E's experience in meeting the most exacting standards in steam generation — those of the electric utility industry for which C-E is currently designing and building boilers which will set tomorrow's standards of capacity, pressure and temperature.

All have demonstrated — in many installations — high standards of performance . . . economy, reliability and suitability for the particular fuel and operating conditions for which they were selected.

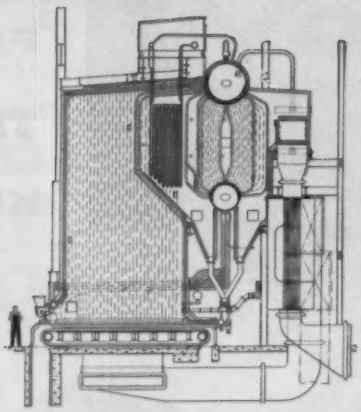
So — no matter what combination of conditions prevail at your plant, Combustion has a boiler unit that can meet your requirement, exactly — and economically. We'd like to discuss it with you and your consultants.

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT; NUCLEAR REACTORS,

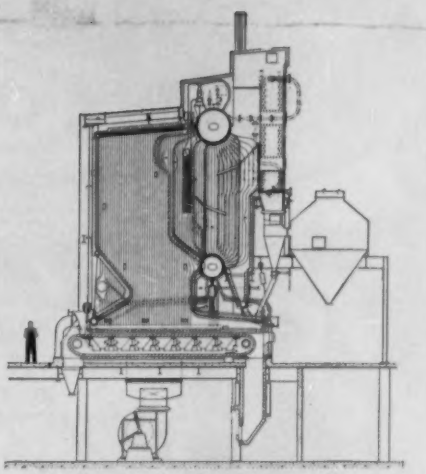
STOKER-FIRED BOILERS*



C-E Vertical-Unit Boiler, Type VU-10 – fired by a C-E Underfeed Stoker, Type E – VU-10 Boilers are available for capacities from 10,000 to 60,000 lb of steam per hr with pressures to 475 psi; superheat to 200 F in larger sizes. Also can be equipped with C-E Spreader Stokers, dump grate type.



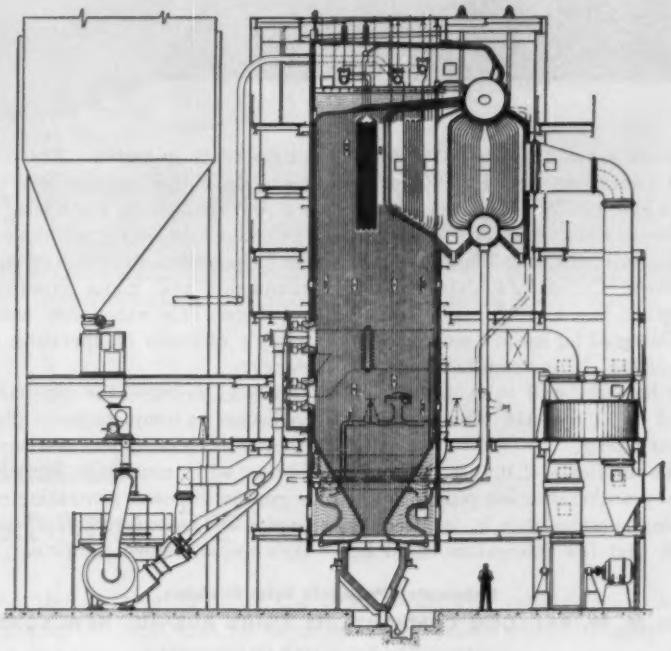
C-E Vertical-Unit Boiler, Type VU-40 – fired by C-E Spreader Stoker, continuous discharge type – A baffleless boiler with capacities ranging up to about 300,000 lb of steam per hr, with pressures to 1,200 psi; temperatures to 950 F.



C-E Vertical-Unit Boiler, Type VU-50 – fired by C-E Traveling Grate Stoker – Units of this design are suitable for capacities up to about 150,000 lb of steam per hr; pressures to 1,200 psi; temperatures to 950 F.

BOILERS

equipment of firing



PULVERIZED COAL FIRED BOILERS*

C-E Vertical-Unit Boiler, Type VU-40 – using C-E Raymond Bowl Mills and Horizontal Burners – Capacities up to 600,000 lb of steam per hr, pressures to 1,200 psi, temperatures to 950 F.

These drawings are a few examples of the many units available for coal firing: all are readily adaptable to oil or gas firing.

COMBUSTION ENGINEERING

Combustion Engineering Building • 200 Madison Avenue, New York 16, N. Y.

Canada: Combustion Engineering-Superheater Ltd.

C-439

PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS; SOIL PIPE

KELLOGG'S FABRICATING TECHNIQUES KEEP PACE

Fabrication of the Type 316 Stainless main steam piping for Philadelphia Electric Company's new Eddystone Station, Unit No. 1, comes nearer to completion—in The M. W. Kellogg Company's Jersey City shops.

Designed for use at a record 5,000 psi-1200 F., these steam lines required the heaviest wall thicknesses ever used in Type 316 steam-electric plant piping.

To fabricate 2,400 ft. of such heavy-walled stainless piping to exacting specifications is, in itself, a task that few fabricators could be entrusted to undertake. For many years M. W. Kellogg has been testing and evaluating materials, and perfecting fabricating techniques, in conjunction with the foremost power companies and major equipment suppliers. This experience assures today's ultimate in operating efficiency.

Kellogg welcomes the opportunity to discuss its complete power piping design, fabrication, and erection facilities with consulting engineers, engineers of power generating companies, and manufacturers of boilers, turbines, and allied equipment.

Photo above, of section of Type 316 piping being welded, dramatically shows ratio of wall thickness to inside diameter. This section has already been bent, in rear, to a 90° angle. Below, welded joints of smaller section of Type 316 being ground to dimensions. The bend on this section is visible at left.

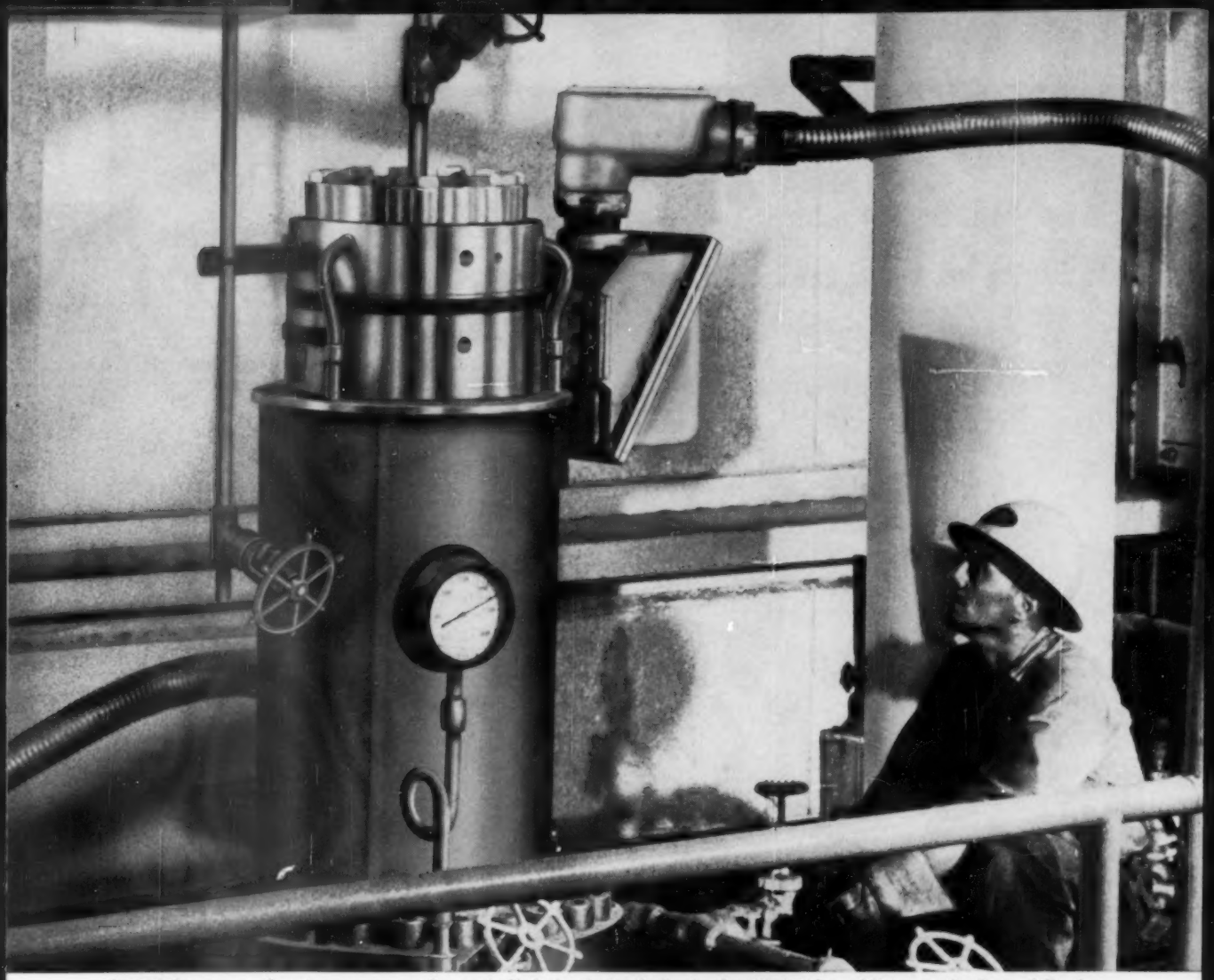
Fabricated Products Sales Division

THE M. W. KELLOGG COMPANY, 711 THIRD AVENUE, NEW YORK 17

A SUBSIDIARY OF PULLMAN INCORPORATED

The Canadian Kellogg Co., Ltd., Toronto • Kellogg International Corp., London • Kellogg Pan American Corp., New York • Societe Kellogg, Paris • Companhia Kellogg Brasileira, Rio de Janeiro • Compania Kellogg de Venezuela, Caracas

POWER PIPING—THE VITAL LINK



One of three canned motor-pumps on the controlled circulation boiler in the 125,000-kw addition to the Seward Station.

PENELEC'S

First annual inspection of Westinghouse Canned Motor-Pumps

Pennsylvania Electric Company reports: after the first annual inspection, the Westinghouse canned motor-pumps on the controlled circulation boiler at the Seward Station were in excellent condition.

One pump was operated continuously throughout the 276 days that the boiler was in service. The other two units alternated between full operation and hot standby. This operating experience demonstrates the trouble-free and reliable service that can be expected from Westinghouse canned motor-pumps.

For information on the advantages of these leak-proof pumps for controlled circulation boilers and other uses, contact your Westinghouse sales engineer, or write: Westinghouse Electric Corporation, Atomic Equipment Department, Cheswick, Pa.

J-57017-R-2

YOU CAN BE SURE... IF IT'S Westinghouse

HERE'S A
SPECIAL ADVANTAGE
OF THE
LJUNGSTROM:®

high availability

These five basic factors assure you that the Ljungstrom Air Preheater will give exceptionally long periods of uninterrupted availability:

1. **UNIFORMLY HIGHER COLD-END METAL TEMPERATURES.** This minimizes the danger of local corrosion due to cold spots.

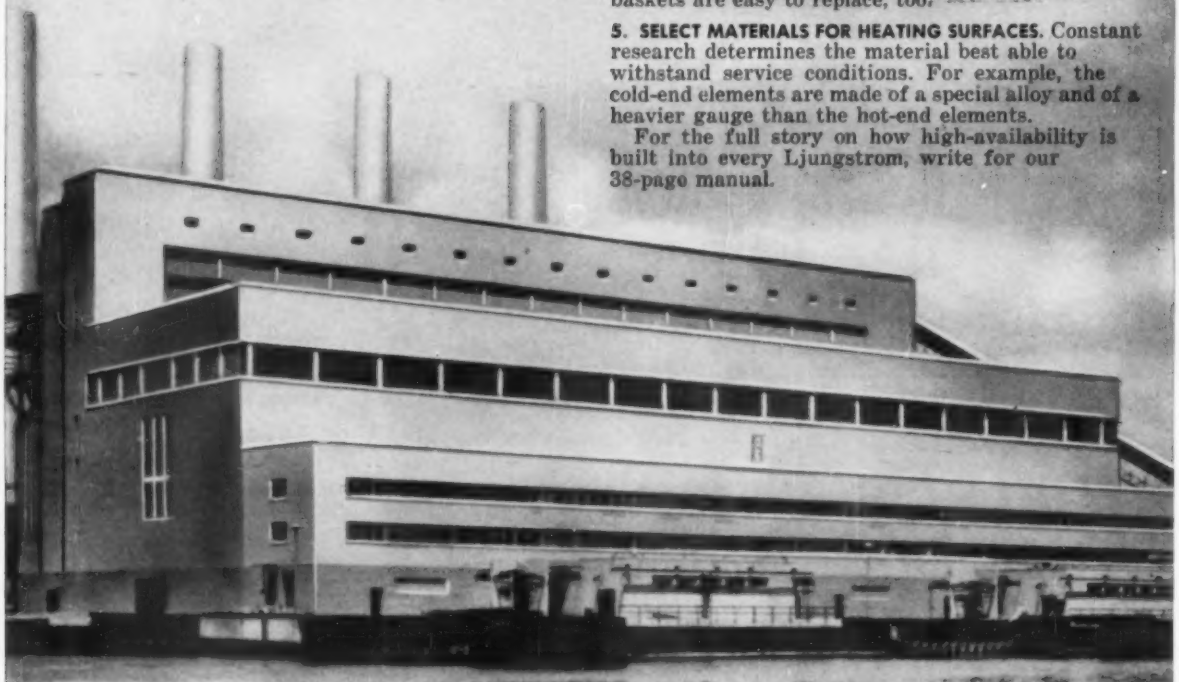
2. **POSITIVE CLEANING ACTION.** A mass-flow soot blower is normally installed at the cold end of the Ljungstrom where deposits are most apt to accumulate. Daily cleaning with superheated steam or compressed air removes any deposits.

3. **INSPECTION PORTS.** You can see for yourself, at any time, the condition of the heating surfaces.

4. **REVERSIBLE COLD-END BASKETS.** Elements in the cold end are separated into small baskets, which can be inverted when one end starts to wear thin. These baskets are easy to replace, too.

5. **SELECT MATERIALS FOR HEATING SURFACES.** Constant research determines the material best able to withstand service conditions. For example, the cold-end elements are made of a special alloy and of a heavier gauge than the hot-end elements.

For the full story on how high-availability is built into every Ljungstrom, write for our 38-page manual.

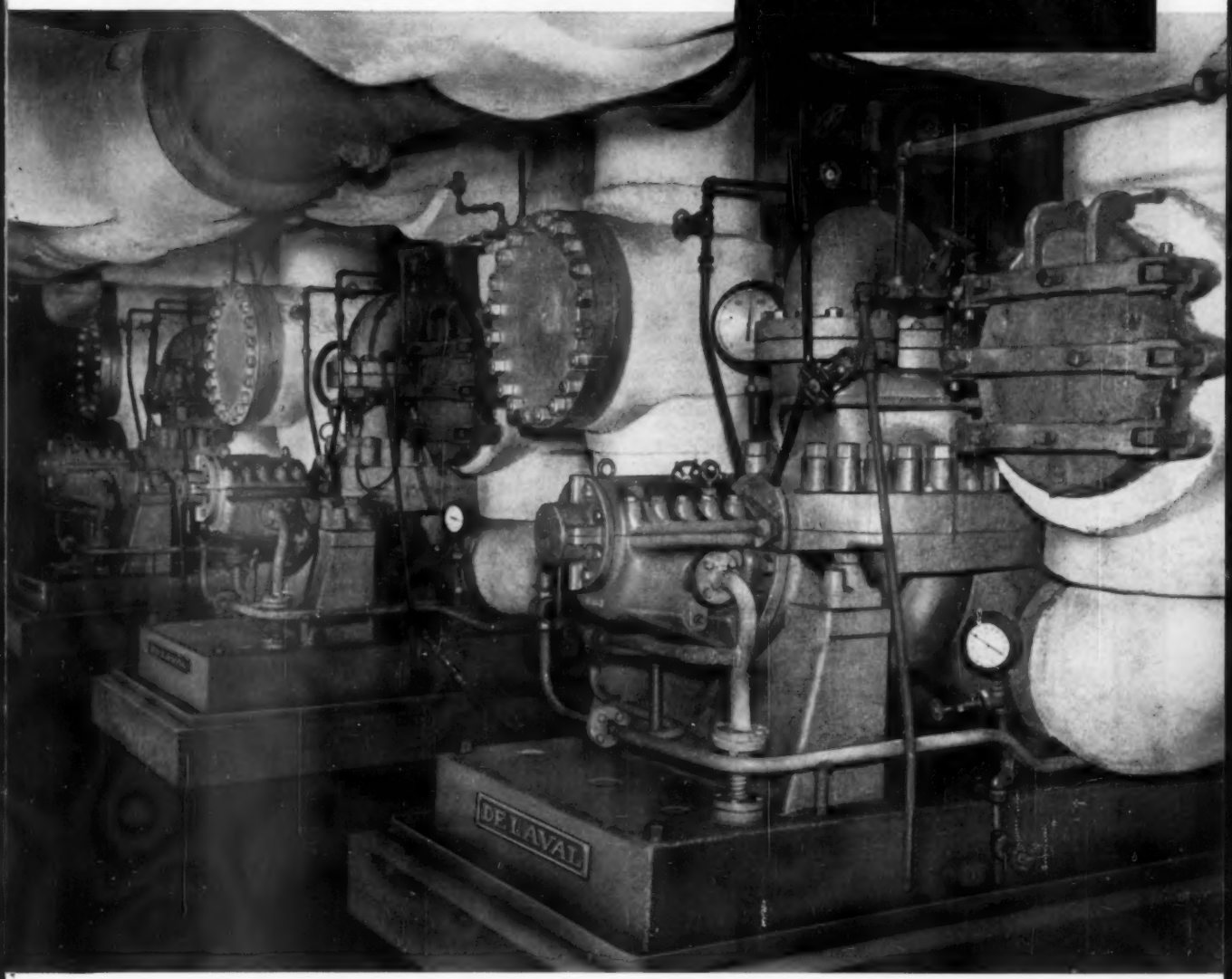


The Air Preheater Corporation 60 EAST 42nd STREET, NEW YORK 17, N. Y.

Con Edison *reorders*

DE LAVAL

BOILER FEED PUMPS



The three De Laval Oppeller Pumps, shown in the photograph, do a dependable job of handling boiler feedwater at the East River Station of the Consolidated Edison Co. of New York. These three-stage pumps, with double-suction in the first stage, have a capacity of 2,000 gpm and operate at a discharge pressure of 620 psig. As proof of their reliable performance, Con Edison has ordered two identical units for the expansion of this station *plus* similar pumps for their Indian Point nuclear generating station.

Excellent for *medium* pressure and temperature service, De Laval Oppeller Pumps are designed with opposed impellers that balance axial thrust. Standard design features include sleeve bearings and labyrinth wearing rings which assure long economical service.

For *high* pressure, *high* temperature boiler feed service, De Laval offers the barrel-type pump . . . a single-suction, radially split diaphragm type multi-stage pumping unit inside a forged steel barrel.

For more data on these dependable pumps, write for Catalogs 1502 and 1506

DE LAVAL *Boiler Feed Pumps*

DE LAVAL STEAM TURBINE COMPANY

886 Nottingham Way, Trenton 2, New Jersey

DL 413

APEXIOR®
in today's power boilers

There's something basic about a power-field product with a job even more vital today than half a century ago — for technologically we've come a whole era since Apexior Number 1® first went to work inside boilers in 1906. The "why" of Apexior and its still-growing use in modern steam generators takes us, then, to fundamentals, best answered by asking—

WHAT IS APEXIOR?

Apexior Number 1® is a high-temperature, non-oxidizing, brush-applied coating for service on both heat-transfer and non-heat-transfer areas. Because it penetrates and becomes one with metal, Apexior seals surfaces at new, or newly cleaned, strength, isolating steel from its environment and establishing it as an independent element in steam generation.

WHY ARE BOILERS APEXIOR-COATED?

Maintaining the status quo to keep steel at peak efficiency is only the first benefit Apexior confers. The simple one-coat process actually transforms steaming surfaces. Because Apexior is smooth and deposit-repelling, metal stays cleaner longer — heat transfer is always at its highest — distribution is uniform — and circulation and evaporation proceed at top performance levels. Off the line, inspection is facilitated — cleaning, when required, is accomplished easily and quickly — and the boiler is soon back in better-than-ever steaming service.

WHERE IS APEXIOR IN USE TODAY?

Now manufactured in the United States and four foreign countries, Apexior serves the world around in electric utility central stations and plants generating power for every kind of manufacturing and service industry. Its first use half a century ago in Scotch marine boilers has been extended also over the years to floating power plants in vessels of every type and size.

CAN YOU APEXIOR-COAT ALL BOILERS?

Apexior serves under highest temperatures and pressures on any steam-or-water-contact area. It may therefore be applied to any water-tube boiler, including water walls, economizers, circulators, and reheat units — and to any fire-tube boiler where it serves on shell interiors and flue exteriors.

WHAT UNIT-SYSTEM AUXILIARIES ARE USUALLY APEXIOR-COATED?

- *Evaporators — interior surfaces, coil exteriors*
- *Deaerating heaters — shells and trays*
- *Feedwater heaters — interior surfaces*

WHAT PARTS OF STEAM TURBINES ARE APEXIOR-COATED?

- *Interior of casings and exterior of rotors, or wheels, and diaphragms.*

MAINTENANCE FOR METAL

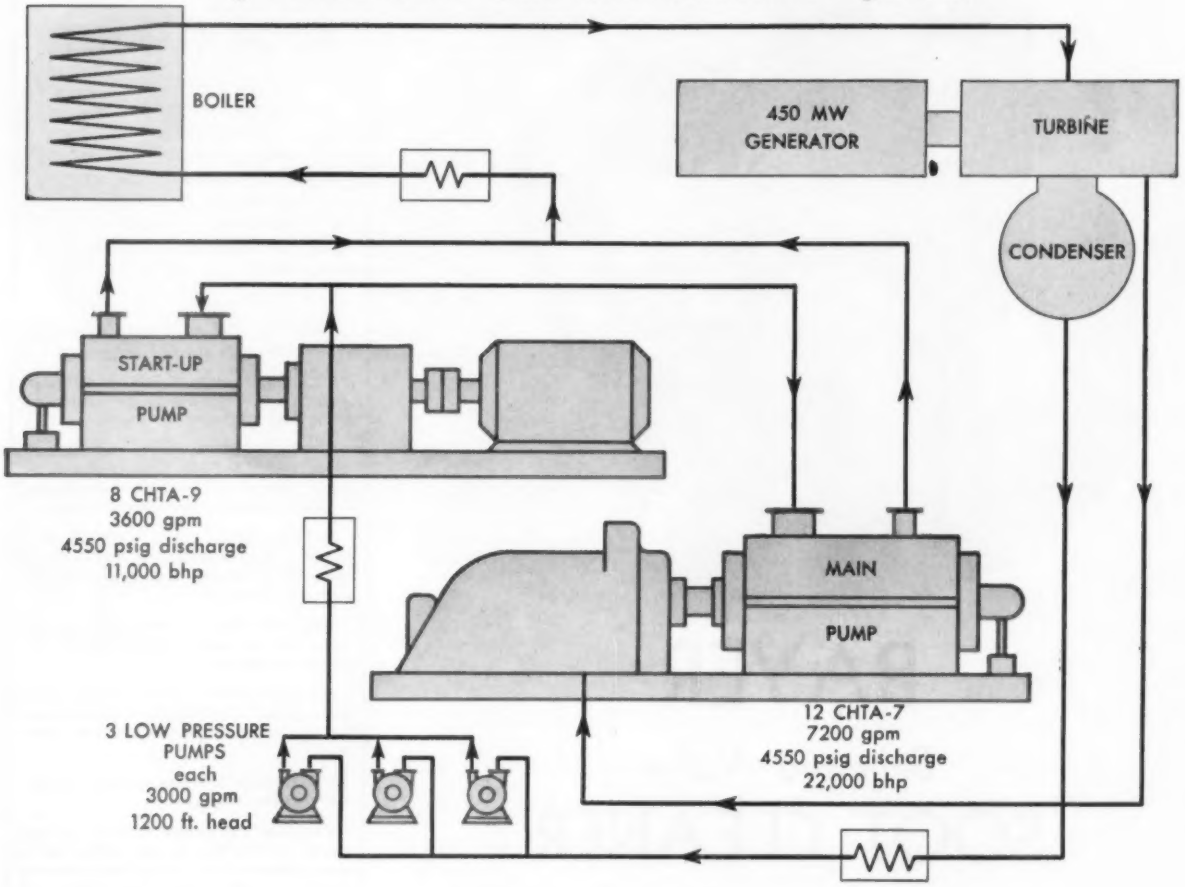
This message is one of a continuing series. To be discussed: Apexior Number 1® in relation to . . . heat transfer, feedwater treatment, high-purity steam, standby, cleaning, cost. Watch for the answer to your question, or write

THE DAMPNEY COMPANY
HYDE PARK, BOSTON 36, MASSACHUSETTS

203

WORLD'S BIGGEST BOILER-FEED PUMPS

will serve two 450 MW Generating Units of American Gas and Electric System



I-R Pumps rated 22,000 hp and 7200 gpm will set new world's record for power and capacity

American Gas and Electric System will make power-plant history with the construction of two tradition-shattering 450 MW generating units — one for a new station operated by the Indiana & Michigan Electric Company and the other for Ohio Power Company's Unit No. 5 at Philip Sporn Station.

Both of these installations will be served by Ingersoll-Rand boiler-feed pumps — 5 units each, connected as shown in the diagram above. Particularly noteworthy is the 7-stage Class CHTA main boiler-feed pump, the largest unit ever ordered, driven by a 22,000 hp steam turbine.

For the highest capacities and pressures, Ingersoll-Rand CHTA boiler-feed pumps are first choice with America's leading power plants. For reasons why, ask your I-R representative.

Ingersoll-Rand

11 Broadway, New York 4, N. Y.

10-701

COMPRESSORS • GAS & DIESEL ENGINES • PUMPS • AIR & ELECTRIC TOOLS • CONDENSERS • VACUUM EQUIPMENT • ROCK DRILLS

THE BAYER CO.

MANUFACTURERS OF BAYER SOOT BLOWERS

For Highest First and Final Value

. . . BUY BAYER!

BAYER

Balanced Valve

SOOT CLEANER

Bayer's single-chain design compels perfect in-step operation of valve and element. Operation is positive, definite, assuring a full flow of steam for efficient cleaning.

When the operator pulls chain, the cam-actuated, quick-action balanced valve is opened. By continued pulling of the chain, worm drive slowly rotates element over cleaning arc. When element reaches end of cleaning arc, valve automatically closes.

Minimum steam consumption—low maintenance. Every detail is engineered, built for long life, efficient performance at high temperatures and high pressures.

More than 30,000 boilers are Bayer equipped. More than 45 years' successful, specialized experience assures you investment economies in Bayer equipment.

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Editorial

An Engineering Heritage Too Long Overlooked

To many people the study of history suggests such elementary school assignments as the memorization of dates, noteworthy battles and great statesmen. Of course, this is no more the essence of history than is the memorization of multiplication tables the essence of mathematics. Unfortunately, however, many engineers who acquire mathematical proficiency far beyond the rote learning of their primary education never undergo similar intellectual growth in the social sciences, and particularly history.

Yet in fairness to engineers practicing today it must be admitted that books setting forth a broad history of engineering have not been readily accessible. Biographies of outstanding engineers (particularly British), detailed accounts of developments in bridge building and steam engine design and histories of venerable engineering companies—all of these have been available in considerable numbers. Also, there have been a number of outstanding published works on the history of science.

This literature deficiency was doubly corrected about two years ago. The Ronald Press Company brought out "History of American Technology" by John W. Oliver, Professor Emeritus in History of University of Pittsburgh (679 pages, $6.50). A companion volume, "Engineering in History" by Richard S. Kirby, Sidney Withington, Arthur B. Darling and Frederick G. Kilgour, was published by McGraw-Hill Book Company (503 pages, $8.50).

The engineer who is interested in viewing current developments in historical perspective will find both of these books quite fascinating. In each of them engineering is considered in terms of its interaction with society and is related to the stream of parallel historical events. "Engineering in History" covers a much longer historical period, considering technical developments as far back as 6000 B.C. Attractively illustrated, it confines its treatment to civil, electrical, mechanical and metallurgical engineering.

As its title implies, "History of American Technology" has a more limited chronological approach and is linked directly to successive industrial developments in the United States. Although lacking in illustrations, this volume contains a great deal of information on specific technological developments, together with bibliographical references that will help the reader to explore topics of interest more thoroughly.

History is a subject which relates man's accomplishments to the passage of time. It is also a subject that many engineers have ignored. Publication of these two books which so effectively complement one another should aid in bringing to a wider audience backgrounds in engineering that have been too long overlooked.

A Visual Qualitative Approach to Duct Design for Power Plants*

By M. J. ARCHBOLD†

Commonwealth Edison Company

The art of designing steam power plants is a changing rather than a static process. It is well, therefore, to periodically review various aspects of design which engineers may come to take for granted and apply in a routine manner. Duct design is an example that fits into this category. Over the years many rules of thumb have evolved, and these are often applied without questioning their adequacy or their validity.

Fig. 1—Barber Colman apparatus for testing flow in ducts

THE increasing size of steam generators and the high efficiency required of dust collectors place a new burden upon the connecting ductwork in a steam power plant. Larger quantities of gas must be handled without undue draft loss, and uniformity of gas flow contributes to the effective performance of dust collectors. Realizing this, the Commonwealth Edison Company undertook studies which were intended to question some of the designs which were then being engineered or fabricated. It was realized, of course, that it would be possible to make accurate wind-tunnel tests of precisely scaled ductwork and precipitator models, something which has been done under special circumstances by dust collector manufacturers providing that time permitted making such studies, without delaying the progress of the work. However, time was not available to study the large number of cases being questioned and it was also desired to have a less costly and more easily adaptable working technique that could give some qualitative indications of the effectiveness of duct design.

Investigation disclosed that laboratory apparatus had already been developed to study flow in heating ducts, and it was found that this could be adapted to study visually the flow of gas through power plant ducts, fans, air heaters and dust collectors. This device, shown in Fig. 1, is essentially a gas flow testing table composed of 2 pieces of plate glass, separated $^1/_4$ in., between which the models to be tested are placed. The models then measure $14^7/_8$ in. by 35 in. long by $^1/_4$ in. thick. Smoke is generated by dropping kerosene on an electrically heated plate, and it is then pumped to a header at the left hand side of the table. This header contains 30 smoke jets, which discharge between the glass plates. Air is brought up between the jets and removed through evenly spaced holes on the right hand end of the table.

Models are mounted on thin, clear sheet plastic. Sponge rubber is used in making up shapes and aluminum for turning vanes. Two plates of glass are spaced approximately $^1/_4$ in. apart, the top plate being hinged. These models can be made from preliminary drawings in a matter of hours, tested in the apparatus and then modified on the basis of visual observations. Thus the engineer can see conditions and improve the design in advance of fabrication and installation of ductwork, thereby avoiding costly field changes.

Importance of Newton's First Law of Motion

Fig. 2 shows the smoke streams passing through the machine without any model or other obstruction between the plates of glass. Due to the friction of the sides of ducts, and because of known turbulence at bends and elbows, it is generally believed that gases flowing through ducts present a rolling and turbulent pattern. This illustration shows the gas flow from left to right across the top of the table and there is practically *no turbulence* in evidence. The smoke jets which have clear streams of air on either side of them, continue to flow in a straight line. This test brings to mind Newton's Laws of Motion. The First Law states that, if a body be at rest, it will remain at rest; or if in motion, it will move uniformly in a straight line till acted on by some force. In duct design this is *definitely fundamental* and should be kept constantly in mind.

* Adapted from a paper presented at the 1957 Electrostatic Precipitator Seminar at Pennsylvania State University.

† General Mechanical Engineer.

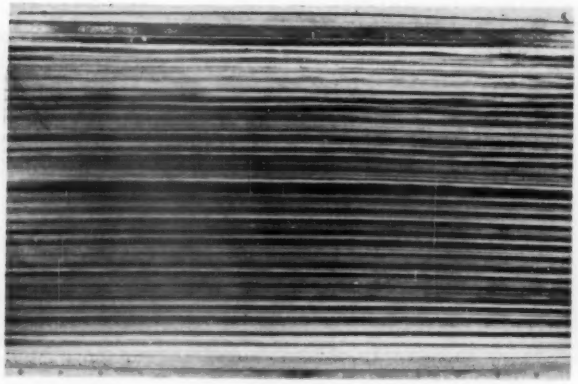

Fig. 2—An example of non-turbulent flow

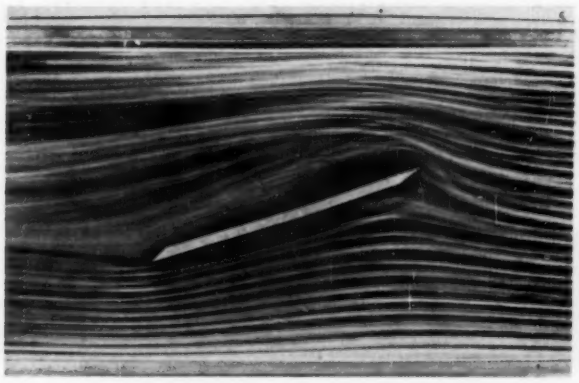

Fig. 3—Effect of a diagonal straight vane

Fig. 3 shows a piece of sponge rubber, simulating a straight vane, placed diagonally across the flow of smoke stream. Straight vanes are used frequently in central station duct systems to deflect the flow of gases where small ducts are expanded into larger ones. This illustrates what happens when a straight vane is placed at an angle in the path of a gas stream. The gas does not respond as the designer had hoped it would, but in contrariness, it may upset, or even worsen the condition which he hopes to improve. This photo was taken at a relatively low velocity; when the gas velocity is increased, a considerable turbulence develops behind the vane. As can be noted, the smoke streams continue to the end of the straight vane, and then travel back up the lee side of the vane, creating a cyclone effect near the entering edge. The greater the angle, the more turbulent the gas becomes on the lee side of the vane.

Use of Vanes for Right Angle Turns

Right angle turns are fairly common in power plant ductwork. Fig. 4 is indicative of the turbulent effects created by two 90 deg turns in series. It shows a considerable amount of turbulence on both the top and bottom outside corners, as well as the inside corners. At higher velocities, the cyclonic effect following the two inside corners becomes quite violent.

Fig. 5 shows a conventional type of vane that often appears in ductwork design. It will be noted that there is a considerable amount of turbulence on the inside corners, since these small turning vanes are too far apart to prevent this situation. To obtain a proper correction, the inside corners should be curved with the same radius as the smaller vane, and additional vanes should be installed to obtain the proper ratio of space between vanes to chord length. For 90 deg turns, the spacing should be in the order of 0.47 of the chord length, and there should be an additional amount of straight vane added to the leaving edge, and parallel to the duct sides. The exact amount to be added will vary with each size of vane, but it should be sufficiently long to prevent blow through.

Fig. 6 shows the same two corners with vanes formed to a true circle. In the top bend these have a long tangent both on the leading and trailing edges, and these are parallel to the side of the duct. It will be observed that except for the second inside corner, the same gas streams are turned fairly well. However, there appears to be a very definite bounce of the smoke in some of the vanes, so that possibly a true circle is not the right shape. Certainly, the straight portion of the trailing edge is necessary, but it is believed that the straight portion of the leading edge is not necessary. It will be noted that the vanes in the second corner do not direct the gases in a straight line following the vane. There is some evidence of blow through on this vane. The large and small vanes are identical as to spacing, radius and so forth, except that the large vanes have the straight tangents added to them.

Flow Improvements with 45 Deg Bends

It is logical to consider bends with a turn of less than 90 deg, and Fig. 7 shows two 45 deg bends. This model has been made of the discharge of an induced-draft fan.

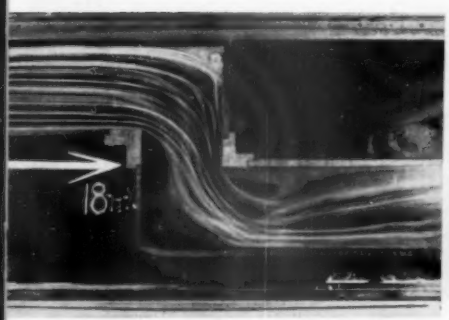

Fig. 4—Two right-angle bends in series

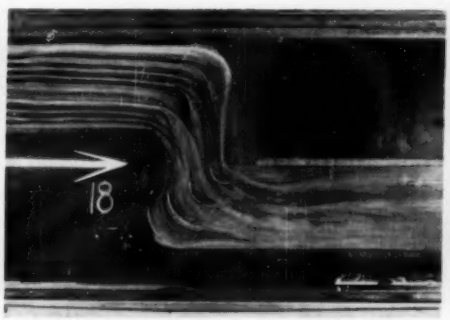

Fig. 5—Conventional vaning for right-angle bends

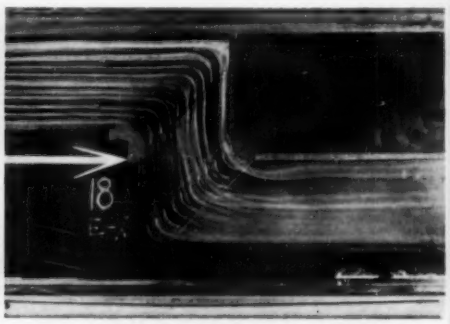

Fig. 6—Flow improvements by close vane spacing

Fig. 7—Two 45 deg bends in series

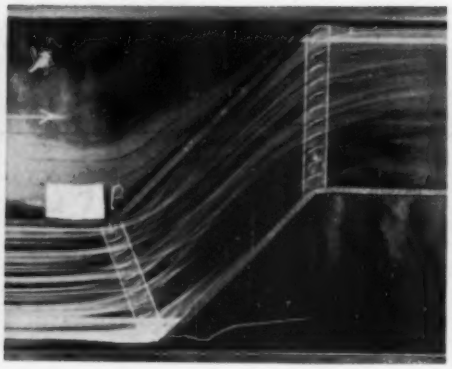

Fig. 8—Application of Keiber vanes to 45 deg bends

Fig. 9— Improved vane design for 45 deg bends

A considerable stream displacement can be noticed even at this low velocity. At higher velocities, there is a considerable turbulence immediately following the bend on the inside corners reaching cyclonic proportions.

Fig. 8 shows the same bends with the Keiber[1] type of vane, and they are spaced in accordance with the table in the reference. By comparing Figs. 7 and 8, it will be noted that these vanes have little effect on turning the gas, and little or no effect on the amount of turbulence following the bend line at the inside corner.

The first set of turning vanes, Fig. 9 (on the left) are scaled 4 ft long, and 1 ft, 6 in. apart. The curvature of the arc has a radius of 4 ft, and the circle is drawn from working points located at a line which bisects the 45 deg bend line. The length of the chord of the arc is 3 ft, and it has a straight trailing edge parallel to the sides of the duct, 12 in. long. The second set of turning vanes (on the right) are spaced vertically 1 ft, 10 in. apart, and are 4 ft long measured along the chord of the vane. The curved section of this vane has a radius of 4 ft, 6 in., and working points o · this radius are located on a perpendicular line drawn 12 in. back of the end of the trailing edge. The chord of the arc of this circle is 3 ft long, and the trailing edge is a straight section one foot in length, and is parallel to the sides of the duct. These vanes have apparently straightened out the gas about as well as can be expected and are a considerable improvement over the ones shown in Fig. 8.

[1] Patterson, G. M., "Corner Losses in Ducts," Aircraft Engineering, August, 1937.

Effect of Beam in Duct

Fig. 10 shows one of the intake air ducts to the forced-draft fan for one of the units in which a beam passes through the duct. There is a metal shrouding around this beam. It was not until this model was made and tested that it was realized that the vane arrangement had produced flows that were not anticipated, and that were detrimental to a uniform pattern. It will be noted that the bottom vane is doing practically no work; as a matter of fact, it appears to be a definite detriment. There is also a turbulent area following the beam, and a very turbulent area following the inside corner. The curvature of the other two vanes is insufficient to provide a certain amount of blow through. When the gas was speeded up, there was a violent turbulence in the upper right hand corner of the duct. At a lower velocity, this is not in evidence. Had these vanes been turned end for end with the long trailing edge downstream, and the short edge tangent to the upstream gas, it is believed that these same vanes would have been much more satisfactory, and that with one located in the upper right hand corner, this corner might have been almost free of turbulence.

In Fig. 11 the shrouding of the beam has been made more streamlined, and large Keiber vanes have been inserted. These vanes have been scaled down for purposes of model testing from their original length of 37.6 in. and spacing of 19.25 in. Space to chord ratio is 0.513.

The same shrouding has been used on the beam in Fig. 12 as in Fig. 11, but smaller Keiber vanes have been in-

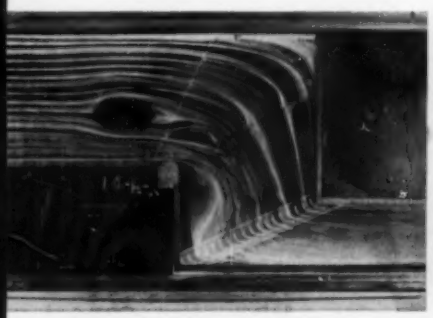

Fig. 10—Influence of beam on flow in duct

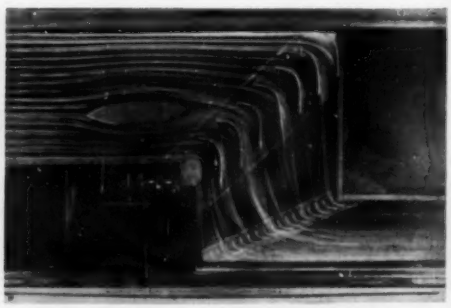

Fig. 11—Effect of large Keiber vanes with beam in duct

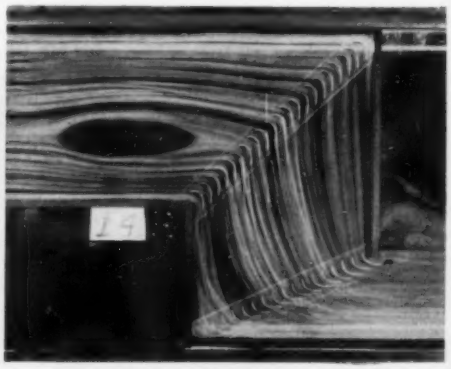

Fig. 12—Effect of smaller Keiber vanes with beam in duct

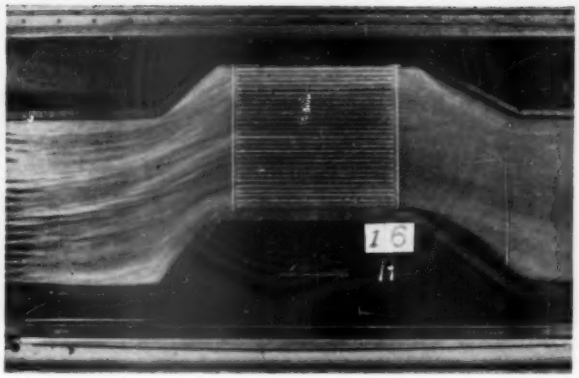

Fig. 13—Flow to and from air heater

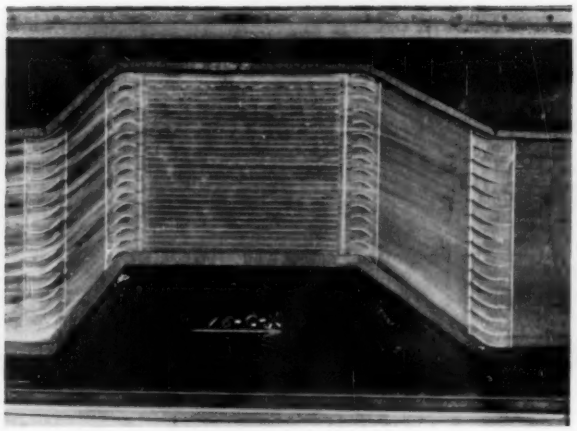

Fig. 14—Improvement of air heater flow by addition of turning vanes

serted. These vanes are scaled from a 12.6 in. length along the chord and a 6.25 in. spacing. The space-to-chord ratio is 0.45. The marked improvement in flow may be attributed to the greater number of Keiber vanes, their close spacing, and their somewhat greater distance from the obstructing beam.

Vanes for Air Heater Ducts

A section of a regenerative air heater is shown in Fig. 13. This section is cut from the outside corner of the rectangular duct to the shaft of the rotor. It should be noted that the duct work goes from rectangular to round, and then from round to rectangular after it has passed through the rotating element. This model shows considerable turbulence on the discharge end on the bottom side, and some turbulence on the top side. With increased velocity, these turbulences become very much more pronounced. Field checks have verified the conditions observed in the model testing apparatus, and there is evidence that the disturbance may have been even more severe in the actual installation.

In Fig. 14 turning vanes have been placed at both the entrance and discharge, creating a uniform flow both entering and leaving the air heater. If such a treatment can be given the air heater transition section, it would improve the gas distribution leaving the air heater, and possibly the distribution going to the dust collector. While this may be very difficult to accomplish, it appears that such a design provides a logical method for minimizing the disturbance. The large vanes in the model are one foot, six inches long and nine inches apart. The spacing-to-chord ratio is 0.50. The large vanes at both the entrance and the discharge could have been improved to some degree had the long tangent on the entering side of the vane been added to the leaving edge. The smaller vanes are one foot long, spaced at six inch intervals, and have a space-to-chord ratio of 0.50.

Fig. 15 provides another example of design considerations in improving gas flow in ducts. Shown in the model is an elbow without turning vanes, the location being below an air heater and ahead of a dust collector. The worst condition, of course, is the inside corner which shows the gases passing far toward the opposite side of the duct. It should be anticipated that any dust in this stream would pass even further to the right than does the gas. At higher velocities the turbulence at the inside corner becomes very pronounced and would be quite damaging to good operation of a dust collector.

Vast improvement is shown in Fig. 16 with turning vanes installed in the corner. These vanes could have a bit longer trailing edge, since they appear to be blowing through, and the gas stream is deflecting to the right. The first set of vanes are spaced 6.2 in. apart and are approximately 14.25 in. long, with a space-to-chord ratio of 0.438. The second set of vanes are the same length, have a spacing of 6.5 in. and a space-to-chord ratio of 0.456.

Single Versus Multiple Vanes

Fig. 17 shows a plan section of the side of the inlet duct leading to a dust collector. The perforated plate for the collector entrance would normally be located at the second bend line. Visual observation shows that the velocity at the collector entrance is far from uniform, apparently being considerably higher at the top of the duct. Subsequent testing has shown that when this velocity is increased sufficiently, the gas becomes extremely turbulent and actually flows backward along the duct at the top of the picture to the first bend line.

One vane was added to the center of the duct, as shown in Fig. 18. This long straight vane appears to have helped very little, if any.

The multiple turning vanes added in the model shown in Fig. 19 have helped in distributing the gases more uni-

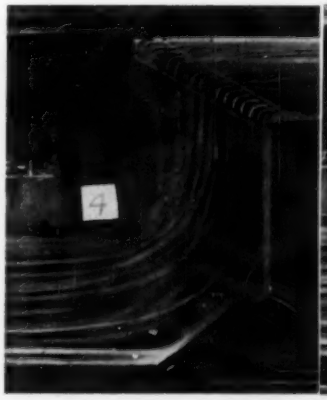

Fig. 15—Elbow between air heater and dust collector, with one set of vanes

Fig. 16—Same elbow as Fig. 15, with two additional sets of vanes

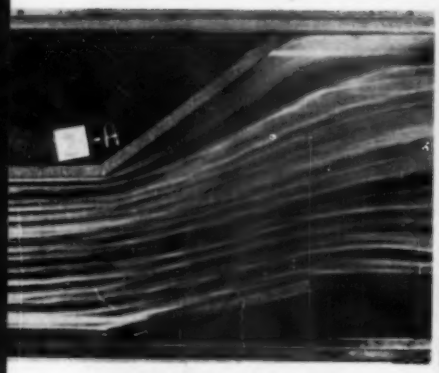

Fig. 17—Dust collector inlet duct without guide vanes

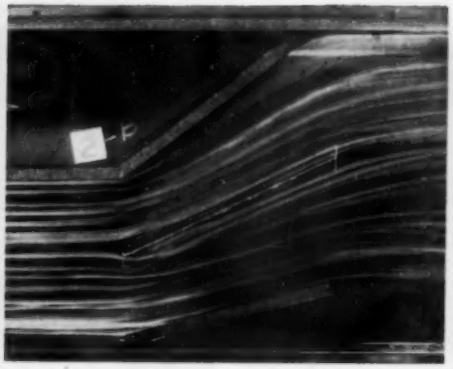

Fig. 18—Same inlet duct as Fig. 17 with single straight vane

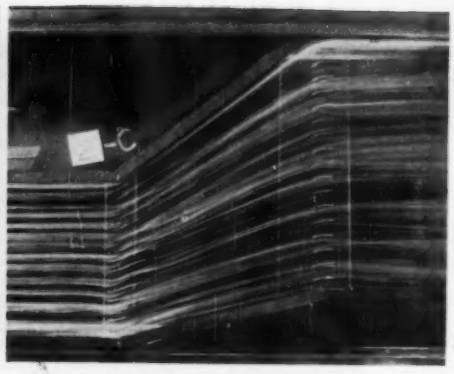

Fig. 19—Same inlet duct as Fig. 17 with multiple curved inlet vanes

formly. Those on the right hand side should have been placed a bit closer together, and possibly should have had a somewhat longer trailing edge. Although some of the streams have blown through without being materially deflected, the pattern on the right hand side of Fig. 19 is materially improved over the single vane shown in Fig. 18. These lines appear to maintain the same pattern through a wide range of velocities.

The length of the first set of vanes shown on the left of Fig. 19 is 24½ in. along the chord, with a spacing of 12.2 in. The other set of vanes on the right are the same length and have a spacing of 16.3 in. The vanes to the left were developed by drawing 15 equally spaced lines parallel to the side of the duct. The bend line to the right was then divided into an equal number of spaces, and lines were drawn from these points to the corresponding horizontal line at the left bend line. A smooth curve was then drawn in the angle formed by the intersection of the two lines.

Dust Hoppers as Sources of Disturbance

Fig. 20 shows a portion of the ductwork between an air heater and a dust collector, including a shallow and a deep hopper. The small triangular section in the vertical duct on the left represents a shelf immediately below the air heater. Field studies of the actual installation confirmed that the shallow hopper caused a bounce in the gas flow, in addition to the turbulence that the illustration shows in both hoppers.

With such turbulence observed in hoppers, the designer may wonder how effectively they are performing their primary function of collecting finely divided material. Fig. 21 shows the vast improvement in flow pattern resulting from covering up the openings to the hoppers and adding two sets of turning vanes, one at the turn line in the center and the other just ahead of the collector on the right.

In Fig. 22 the lower portion of the last set of turning vanes has been omitted. It can be seen that elimination of these vanes has had an indistinguishable effect upon the flow pattern and offers a possibility of cost saving.

Combining Divided Ducts

Fig. 23 shows the plan view of half of a dust collector. After leaving the air heaters the gas flows through two ducts on the left hand side and goes through a plenum chamber at the dust collector, and then to the four inlets of the induced-draft fans on the right. While the scale of the model is a bit small to provide an accurate measure of the flow pattern, it appears that the flow is badly disturbed at the top, center and bottom of the dust-collector inlet. There is a considerable amount of turbulence in the form of cyclones at the center of the plenum chamber. This is what might be expected from a design with a blunt area such as this.

The turning vanes at the first bend line of Fig. 24 have improved the distribution of gas, as might be expected. Had these vanes been longer and more closely spaced in

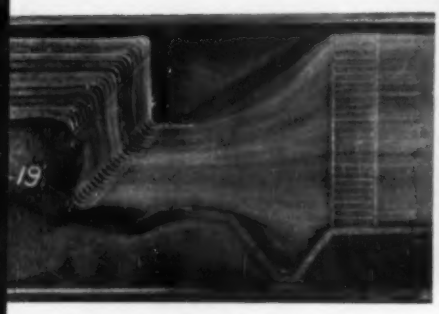

Fig. 20—Turbulent effects in hoppers ahead of dust collector

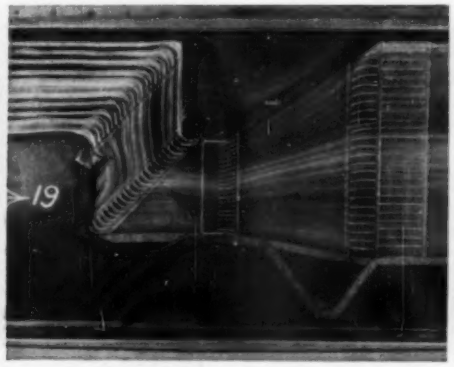

Fig. 21—Flow improvements resulting from elimination of hoppers shown in Fig. 20

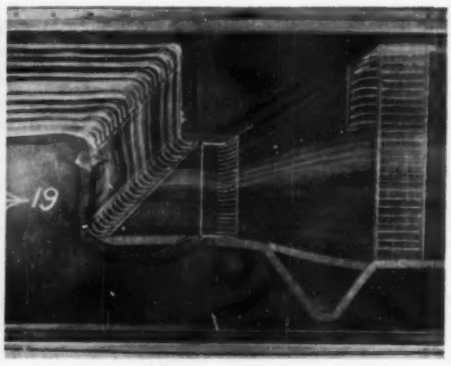

Fig. 22—Elimination of bottom portion of last set of turning vanes of Fig. 21

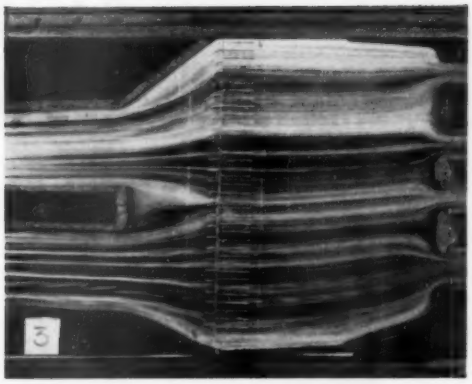

Fig. 23—Flow through portion of a dust collector

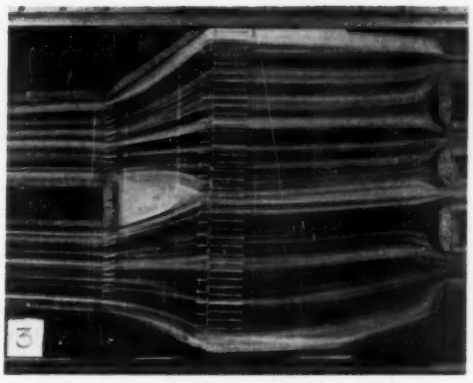

Fig. 24—Improvement of flow of Fig. 23 by addition of vanes at bend line

accurate positions, there would have been a very uniform pattern at the dust collector entrance, except for the turbulence in the center.

Since the turbulence is created by the lower pressure in the space between the two ducts, an obvious suggestion for sharply reducing or minimizing this disturbance is to bring gas into this area through another duct. Fig. 25 shows the effect upon flow of having gas enter this area through a duct midway between the two large ducts. All that has been accomplished has been to break the large turbulent area into two smaller ones.

In Fig. 26 the gas has been brought into the center section behind a perforated plate. The stream from this plate is quite smooth. Further experimentation might well prove that this is a practical method of eliminating this turbulence.

Once again in Fig. 27 the center stream has been blocked off and the vanes moved out from the island in the direction of the gas flow. In this arrangement, which works quite well, the middle vanes act as scoops and bring some gas in back of the perforated screen between the vanes.

Fig. 28 shows the addition of plates in the form of a V extending across the plenum chamber. By comparison with the preceding illustrations, it can be seen that these plates produce a superior pattern of uniform flow. However, installation of the plates prevents the use of the approach ducts as a plenum chamber and involves substantial cost, estimated to range between $7 and $9 per square foot of surface.

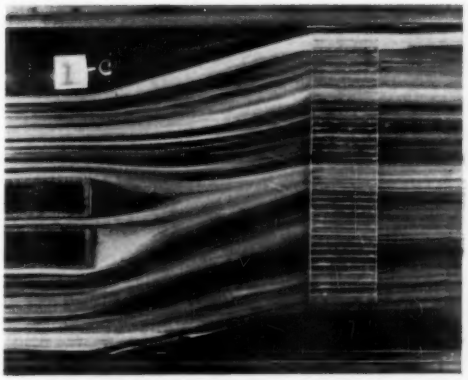

Fig. 25—Effect of adding gas between divided ducts

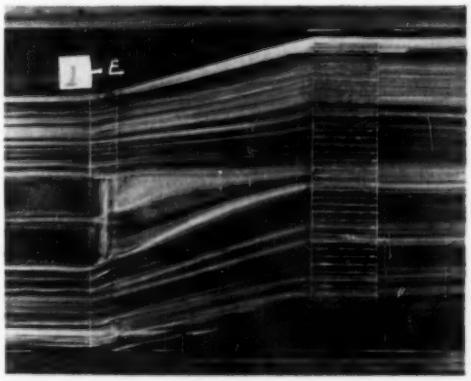

Fig. 26—Improvement through addition of a perforated plate

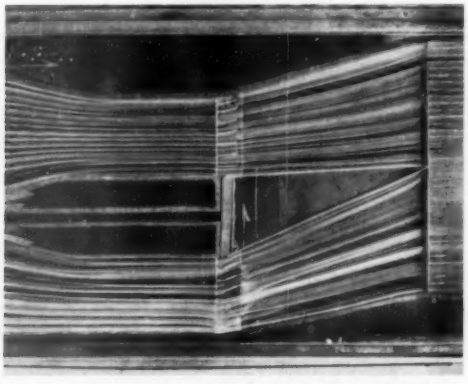

Fig. 28—Flow improvement through addition of V-plates

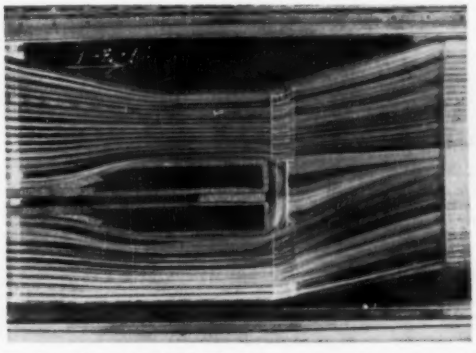

Fig. 27—Center blanked off and vanes moved out from island

Photographic Technique

The photographs reproduced in this article were taken with a 4 × 5 Graflex on Royal Panchromatic film with a photo floodlight at each end of the apparatus. The internal lights of the experimental equipment were used, but the room lights were turned off. Exposure was $^1/_{50}$ sec at *f*11.

Summary

As in any other technique there are limitations in the visual approach to duct design. For example, the model testing apparatus ideally should be more versatile, capable of producing velocities approaching those found in the field. It would also be highly desirable to be able to measure the actual velocity of the model testing machine and to measure pressure drops across turning vanes in order to determine losses. As a further refinement, it would be advantageous to have experimental apparatus with jets on one side, as well as the end, and with air suction on the opposite side as well as the opposite end. However, based on tests conducted thus far, it is apparent that under correct conditions with properly installed vanes, velocity has little effect upon flow patterns. Under these conditions the gases travel in a straight line from the turning vane and no turbulences are picked up. With improper duct design, on the other hand, turbulences are quickly created and increase markedly with increase in gas velocity.

The major advantages of the visual approach to duct design are its simplicity and low cost. With the existing apparatus it is relatively easy to make scale duct sections from preliminary drawings and insert them for testing. In fact, models and testing may be completed in a matter of a few days if quick decisions are urgent. Changes made during the testing of the model itself may then be incorporated in later design drawings. In this manner it is possible to improve duct arrangements during preliminary design instead of making costly field changes at a later date. While not as refined quantitatively as three-dimensional wind-tunnel testing, the two-dimensional visual approach is a relatively inexpensive, quick and effective working tool of the power plant designer.

Acknowledgments

Many persons and organizations were of assistance to the author in performing these experiments. He wishes to express his personal appreciation to Walter Kennedy, director of research of Barber Colman Company and to the engineering staff of Research Cottrell, Inc.

Correction Notice

John Angelo, co-author of the paper "Observed Effects of Deposits on Steam Turbine Efficiency", presented by Mr. Angelo and K. C. Cotten at the Annual Meeting of the ASME in December has called our attention to an error in the abstract of that paper. We reported the total energy generated in 1956 as being 6×10^8 kwhr. This should be 6×10^{11} kwhr.

pd

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"Joe, you wouldn't buy the engine of your car from one manufacturer, the wheels from another and the body from still another, would you? Neither would I. And when I design for induced draft, I specify a P-D Stack because the I.D. Fan, though it is important, isn't the whole story. The combined breeching, stack and fan, built as ONE apparatus, gives me unit responsibility, compact design, simplified engineering, and positive performance, with a lot less purchasing details.

"Another thing, I'd rather buy my Dust Collector from the same manufacturer that made my Stack and Fan. For this is all part of the same system for handling the gas after it leaves my boiler unit.

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The A B C's of Demineralizing

A . . . What it is
B . . . How it is made
C . . . How to plan your system

By F. N. KEMMER

National Aluminate Corporation

DEMINERALIZATION, or deionization, is now a common chemical method of producing high quality water. Chemical reactions which remove impurities from water are carried out by ion exchange resins.

Impurities found in natural water supplies were once minerals of the earth and gases of the atmosphere. These dissolved substances tend to revert to their original form when their environment is changed: when water is heated, aerated, evaporated or perhaps merely agitated. As they return to their original form, these materials create troublesome problems in industry—cause scale and deposits to accumulate in plant equipment, corrode piping which conveys water through the plant, and give rise to so many difficulties that proper handling of water becomes an important problem in virtually every industry.

Many impurities ionize in water and become able to conduct electric current, Fig 1. Water's resistance to current flow thus becomes a simple and effective means of measuring the salinity of water, Figs. 2a and 2b. By industrial standards, "pure water" is one with low concentration of dissolved materials and therefore a high electrical resistance. This is quite different from the concept of purity involving potability and bacterial count in water intended for human consumption.

A—Demineralization and Distillation

The concept of "pure water" once associated with distillation has been modified by the ion exchange process. Distilled water has always been quite expensive to produce. Few industries could afford distillation of large volumes of water except for special applications. Lower costs of demineralizing average water supplies by ion exchange have made high quality water available in large quantities for many uses.

Distillation is the removal of a large proportion of water vapor from a very dilute salt solution (a category into which natural water supplies fall), leaving a more concentrated solution (waste), and vapor which must be condensed into distillate with loss in heat. Heat loss inherent in the distilling process is the reason for the high cost of distilled water, Fig. 3. As contrasted to distillation, demineralization by ion exchange removes the salts themselves from the raw water, producing finished water free of salts. These removed salts are periodically discarded by chemical regeneration, Fig. 4.

B—Basic Demineralization Methods

There are many modifications of the demineralizing process, all comprised of three fundamental units: the cation exchanger, the degasifier and the anion exchanger.

Cation and anion exchangers may perform in either "batch or column" fashion. In batch performance, both exchangers may be mixed with the water to be treated, then settled to permit drawing off finished water. This procedure applies only to small scale apparatus: for production of demineralized water for home use (in steam irons), or for a limited industrial use (the filling of storage batteries or the furnishing of reagent water for chemical testing in the field). Practically all industrial demineralization, is performed in column operation. Water passes continuously through a column of ion

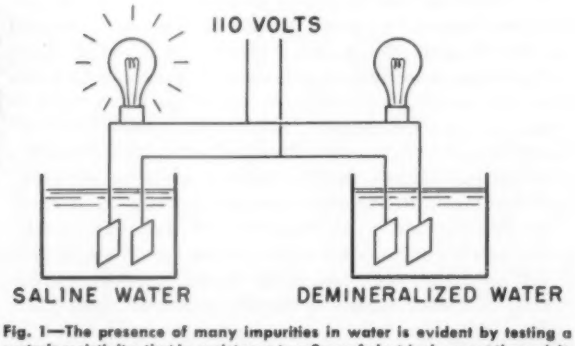


Fig. 1—The presence of many impurities in water is evident by testing a water's resistivity, that is, resistance to a flow of electrical current through it. Salt water conducts, demineralized resists

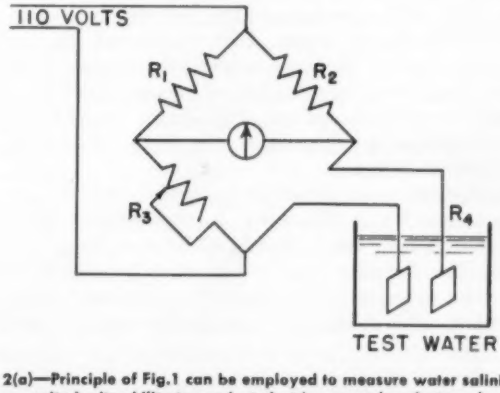


Fig. 2(a)—Principle of Fig.1 can be employed to measure water salinity or purity by its ability to conduct electric current (conductance)

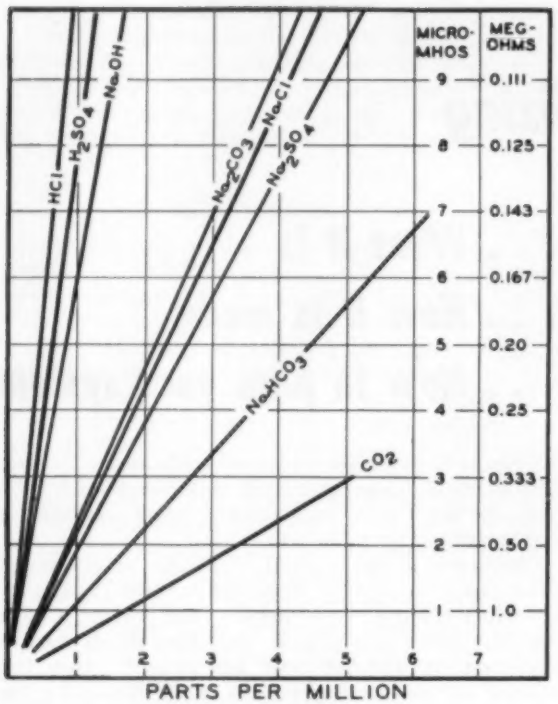


Fig. 2(b)—The ability of various salts in water to conduct current shows how concentration and species affect conductance

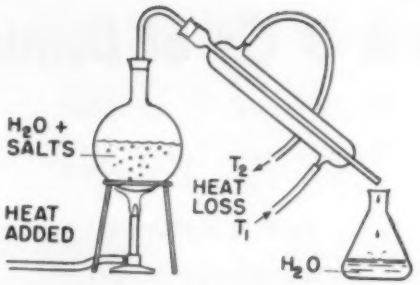


Fig. 3—Pure water can be produced at the expense of heat energy by distillation

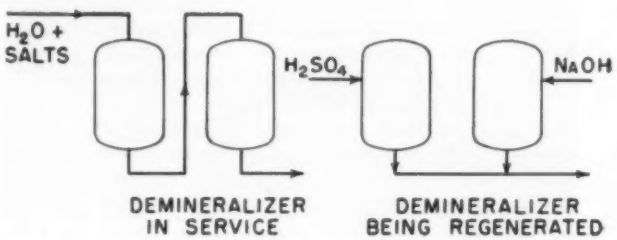


Fig. 4—Pure water can be produced at the expense of chemicals with ion exchange

exchanger in a suitable container until the exchanger capacity has been consumed.

Cation Exchange

Simplified, the cation exchanger consists of a bed of high capacity cation exchange resin (Nalcite HCR).* The resin is an insoluble material having a network to which cations are attached. In a demineralizer the resin is regenerated with an acid and its function is to convert salts in the water supply to their analogous acids. The water usually passes through the cation exchanger from top to bottom. As the cation resin relinquishes its hydrogen ions in exchange for ions in raw water (calcium, magnesium and sodum), it gradually becomes depleted and in time requires regeneration. In this respect, it may be likened to a storage battery.

Regeneration is accomplished by reversing the process, passing acid through the exchanger to force hydrogen ions in the acid to return to the network, releasing accumulated cations which have saturated the resin. Completeness of this regeneration determines how effectively the exchanger is able to convert salts into acids during its next period of use. The more completely a cation exchanger is regenerated, the higher the purity of the finished water.

In operation, a cation exchanger converts natural salts in raw water to acids. To demonstrate this, the cation exchanger can be dyed and its performance easily followed as the acid form is converted to the salt form. The color changes, as the water flow gradually exhausts the resin. When the color has all changed, the acidity of water leaving the exchanger decreases as the salt content begins to escape unchanged through the bottom.

Cation Exchanger Regeneration

When an exchanger is exhausted, it is taken out of service and regenerated in this fashion:

(a) Raw water is passed through the exchanger bed from bottom to top. As water flow increases, the beads rise and the bed expands until the beads are in balance with the force of water flowing between them. The expanded bed then reaches a fixed level. There are two purposes in this first step of regeneration: First, most water supplies contain fine particles in suspension, often so minute as to be invisible to the naked eye. Backwashing floats these accumulated solids from the surface of the bed. Second, continued flow of water through the bed in normal service, hour after hour, slowly compresses the bed. Backwashing "fluffs" the bed so that compression is relieved and flow is facilitated.

(b) After the bed has been cleaned, accumulated cations are released by passing a weak acid solution through the bed. Again, if the bed is dyed, it will change color as hydrogen ions become attached to the resin and displace the accumulated cations. It is not economical to regenerate an exchanger completely, because this requires large excesses of chemical. In industrial demineralizing plants, proper balance between capacity, acid cost and water quality must be carefully considered.

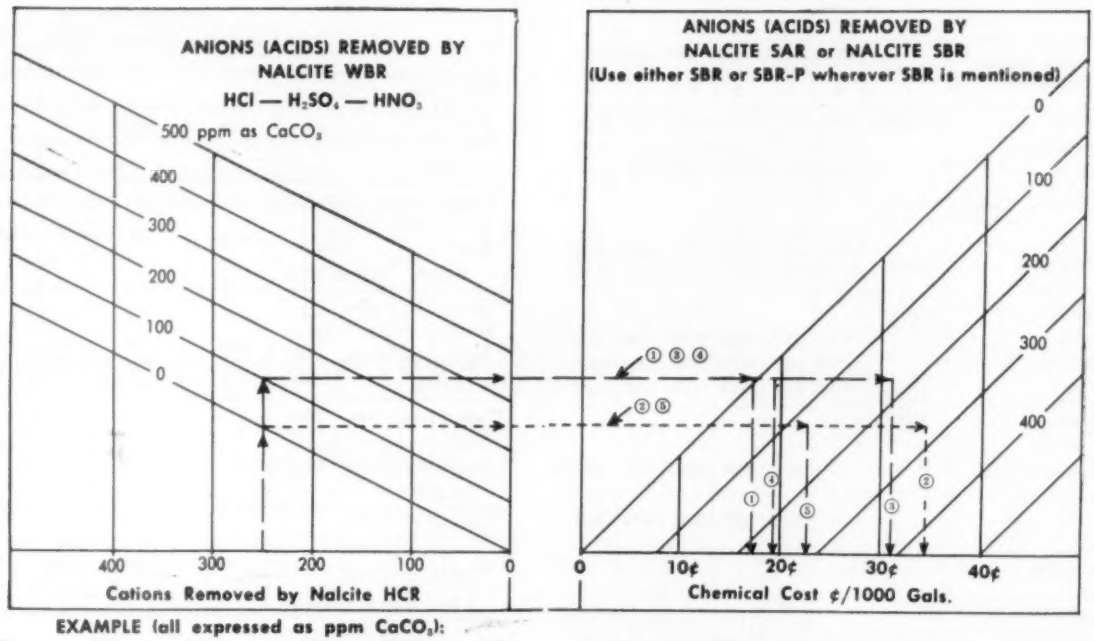
(c) During acid treatment, some of the acid actually soaks into the resin beads and must be rinsed out so that it will not waste the capacity of the anion exchanger following it. Raw water is usually used for rinsing.

Degasification

A degasifier is a unit which removes dissolved gases

* The terms Nalcite, HCR, SBR, SAR and WBR are registered trademarks of National Aluminate Corporation.

DEMINERALIZER OPERATING COSTS



EXAMPLE (all expressed as ppm $CaCO_3$):

Ca	150	SO_4	50	HCO_3	150
Mg	50	Cl	50	CO_2	10
Na	50	NO_3	0	SiO_2	10
Cations	250	Strong Acids	100	Weak Acids	170

① HCR-WBR for High Quality Process Water.

② HCR-SBR for Peak Quality, Silica-Free Water, Minimum Capital Cost.

③ HCR-WBR-SBR for Peak Quality, Silica-Free Water.

④ HCR-Degasifier-WBR-SBR for Peak Quality, Silica-Free Water, Reducing Chemical Cost by Mechanical CO_2 Removal.

⑤ HCR-Degasifier-SAR for Peak Quality, Silica-Free Water, Eliminating WBR to Save Capital Cost, at Higher Chemical Cost.

physically, either by creating a vacuum environment, or by scrubbing the water with a stream of air. Carbon dioxide is generated from the natural alkalinity of raw water as it passes through the cation exchanger. Mechanical removal of this gas reduces the work which must be done chemically, lowering overall costs. A degasifier is not always an economic requirement, however, because it is an additional piece of equipment to buy and maintain. Its expense may eat up any savings realized.

When a degasifier operates under vacuum, it not only removes carbon dioxide, but oxygen as well. This results in finished water somewhat less corrosive than that produced by a degasifier exposed to the atmosphere. In the atmosphere type degasifier, although carbon dioxide is efficiently removed, the water is saturated with oxygen. While the atmosphere type degasifier is less costly, saturation of the water with air and also the possibility of introducing contamination from the atmosphere often overcome cost advantages it may possess.

Anion Exchange

The third fundamental unit is the anion exchanger. There are two major classes of anion exchange material. One, called a weakly basic exchanger (Nalcite WBR),* can remove only the strong acids (such as sulfuric and hydrochloric) produced by a cation exchanger. The second, a strongly basic exchanger (Nalcite SBR, SBR-P and SAR),* is able to remove all acids, including those not considered acids such as silica and carbon dioxide.

Regeneration of a weakly basic anion resin is simply a neutralization of accumulated acids. It can be regenerated not only with caustic soda, but also with soda ash or ammonia. In regenerating strongly basic resin, the chemical not only neutralizes acids, but converts the exchanger itself into a strong base—that is, a network to which hydroxyl ions are attached. Therefore, caustic soda is necessary for regeneration of the strongly basic resin. Salts released during regeneration must be rinsed from the resin beads and from the unit to achieve the high quality water available from this type of unit. The final rinse requires a source of water of good quality, such as that produced by the cation exchanger.

Demineralizer Systems

With these basic units, cation exchanger, degasifier, anion exchangers, a variety of demineralizing systems can be arranged. These are called multibed demineralizers because a bed of each resin is contained in its own individual vessel.

There is a second important group of demineralizing systems, classed as mixed-bed demineralizers. These units are unique in that the cation and anion exchangers function in a single vessel. Being of different densities, the resins separate during backwashing, permitting regeneration with their respective chemicals without cross contamination. After the resins are rinsed, they are thoroughly mixed, usually by air agitation. This intimate mixture is a bed of material containing many cation and anion particles operating in series. This results in extremely effective removal of salts from the water, and produces finished water free of measurable salinity.

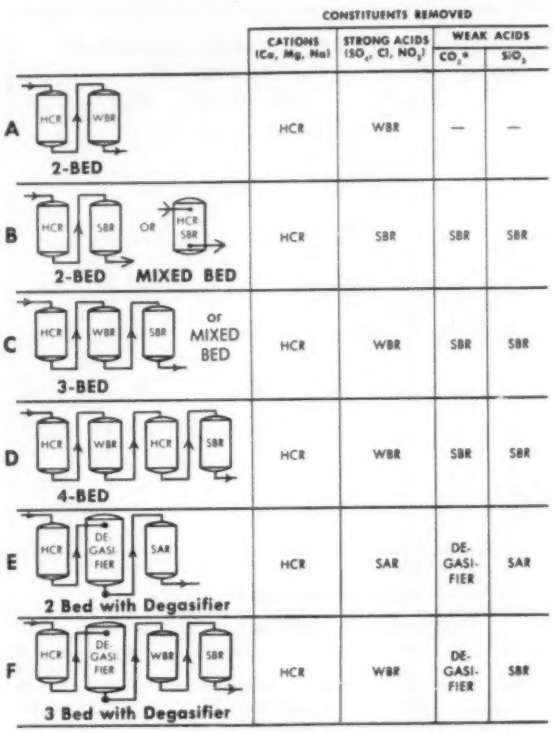
*Disposable cartridges make up a third group of de-

NALCITE RESINS USED

RAW WATER CONSTITUENT	PPM as	RESINS USED TO REMOVE EACH CONSTITUENT — PROCESS A	B	C	D	E	F
Calcium	$CaCO_3$	HCR	HCR	HCR	HCR	HCR	HCR
Magnesium	"	HCR	HCR	HCR	HCR	HCR	HCR
Sodium	"	HCR	HCR	HCR	HCR	HCR	HCR
Total Electrolyte	$CaCO_3$						
Bicarbonate	$CaCO_3$	Converted to CO_2	Converted to CO_2	Converted to CO_2	Converted to CO_2	Removed As Gas*	Removed As Gas*
Carbonate	"	"	"	"	"	"	"
Hydroxl	"	—	—	—	—	—	—
Sulfate	"	WBR	SBR	WBR	WBR	SAR	WBR
Chloride	"	WBR	SBR	WBR	WBR	SAR	WBR
Nitrate	"	WBR	SBR	WBR	WBR	SAR	WBR
M Alk.	$CaCO_3$						
P Alk.	"						
Carbon Dioxide	"	—	SBR	SBR	SBR	SAR	SBR
pH							
Silica	"	—	SBR	SBR	SBR	SAR	SBR
Iron	Fe						
Turbidity							
TDS							
Color							
RESIDUALS	PPM as						
Electrolyte	$CaCO_3$	1-2	0-2	0-2	0-2	0-2	0-2
Silica	"	10	NIL	NIL	NIL	NIL	NIL
CO_2	"	160	NIL	NIL	NIL	NIL	NIL

*CO_2 residual may be about 8ppm after degasifier.

BASIC TYPES OF DEMINERALIZERS



*CO_2 Results from Alkalinity Converted by Nalcite HCR.

mineralizers Although the cartridges are of small size, they are an important contribution to the production of high quality water for laboratory work, and for other applications of modest requirements. They comprise a disposable cartridge containing cation and anion resin, mounted in a permanent stand, often complete with a purity indicator. Ion exchange resins may be dyed, so that as the resin becomes exhausted it will change in color to indicate that replacement is necessary.

C—How to Determine Demineralizer Needs

All demineralizers require a cation exchanger, preferably with a high capacity cation resin (Nalcite HCR).

1. What quality water does the plant need?

If it is process water, there is a good chance that complete removal of carbon dioxide and silica is unnecessary. Here, a weakly basic anion resin (Nalcite WBR) may be used to take advantage of its excellent chemical efficiency. When peak quality is needed, carbon dioxide and silica must be eliminated, and a strongly basic resin (Nalcite SBR, SBR-P, SAR), is selected.

2. How much water is required?

Usually, if water demand is less than about 50 gpm, the plant will benefit from the simplest piece of equipment, at a sacrifice in chemical operating cost. This is one reason it is common to find mixed-bed demineralizers widely used for modest plant requirements, since both the cation and anion resins are contained in one unit. On the other hand, when plant demands exceed 200 gpm, it is almost certain that several units will be built into the demineralizing system, and one will probably be a degasifier if the raw water alkalinity is higher than a 50–100 ppm range.

3. What about extent of capital investment?

In chemical plants, management often requires a fast payout on equipment. Simple arrangements are often preferred to reduce investment at the expense of higher operating cost. At the other end of the scale are the utilities which strive for economy, investing additional capital to achieve it.

These factors influence the selection of an anion exchanger to follow the cation unit. Each anion exchanger does a specific job. Weakly basic resin (Nalcite WBR) removes strong acids (sulfates, chlorides and nitrates) with good chemical efficiency. Strongly basic resin (Nalcite SBR, SBR-P, SAR) removes the strong acids, too, but not as efficiently. These resins, however, do a job that weakly basic resins cannot do; removing weak acids (carbon dioxide and silica). There is a choice between two types of strongly basic resins: Type I (Nalcite SBR, SBR-P) and Type II (Nalcite SAR), the first being used when the proportion of weak acids is high, and the second when the proportion is low.

To illustrate these points, Table, p. 43 gives a raw water analysis and shows the chemical cost of treatment with a variety of demineralizing processes. Table, left side, p. 44, shows which constituents are removed by each of the demineralizing units.

Using the chart, table, p. 43, chemical cost for production of the quality of water required can be determined for any water supply. Leading equipment manufacturers can provide details as to equipment costs, and how they vary from one demineralizing layout to another.

The problem of the fully automatic packaged boiler and its acceptance as an absolutely fail-safe device is again aired with a case history to point up the author's contention (shared, we might add, by most designers and manufacturers) that the automatic unit of today requires good supervision and excellent maintenance.

By K. D. CILLEY

Mutual Boiler and Machinery Insurance Co.

Automatic Boiler Operation

THE day on which boiler operation can depend entirely on automatic controls without incident has not yet been completely attained.

There are numerous so-called package boiler units of both fire and watertube types being operated today without constant attendance as automatic control is relied on through time clocks to start and stop boiler operation. The water level is also controlled automatically through float, probe or temperature instrumentation followed by a similar automatic control for shutting off the fuel supply should the water within the boiler drop below a predetermined safe operating level.

This automatic operation has had a somewhat lulling effect on personal attention, and, like many features of automatics is neglected until some instrument does not function as designed and trouble is experienced.

The following is an account of a recent development having taken place in an industrial plant where supposedly constant attendance was provided in the boiler room, however, for a short period the automatics took over.

Constant Vigilance

Automatic controls appear to have a feature of seldom or, as in this case, never failing while under constant surveillance, but when the attendant stepped out of the boiler room for a short period of time, the low-water cutoff failed to function and only by the best of luck was disaster avoided.

The incident referred to developed in a Scotch marine type boiler of 125 psi design, installed alongside two brick-set boilers of the standard HRT type which had been converted to oil firing.

The Scotch was of the package type, and because of automatic controls was used as an auxiliary during peak loads as well as during low loads or on weekends for heat and light processing.

This seven-year-old, 72-in. boiler was of all-riveted construction with a 36-in. corrugated furnace of $^{3}/_{8}$-in. thickness. It was fired by oil with the usual fuel oil heaters, float controlled, low-water cutoff, automatic pump control, but with a conventional feedwater regulator of the manually adjustable type without the benefit of a bypass.

This type of regulator was purposely installed in this manner so that feedwater to the boiler would be controlled but, unless the control was in operation, the boiler was not to be operated.

At this particular time, the boiler had been in operation throughout the day in conjunction with a neighboring boiler at a reasonable load. At the time of change in operating personnel during the last afternoon shift,

Fig. 1—Front view of an overheated and collapsed portion of a corrugated furnace of a Scotch marine boiler. Blister measured 17-in. across, 18-in. deep

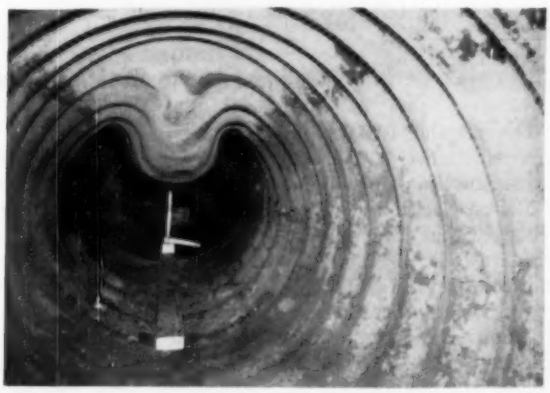


Fig. 2—Rear view of the same furnace blister of Fig. 1. This was caused by a feedwater starvation from insensitive low water cutoff and feedwater regulator action

the load reduced to some extent and the fireman throttled down the feedwater regulator because of the lesser demand for steam and subsequent feedwater. He, then, thinking all in order for automatic operation, stepped away from the boiler room for an undetermined period of time. During this interim, as is often the case, things began to happen. First, evaporation was naturally taking place in the boiler; secondly, the feed regulator was apparently throttled below the evaporation rate; thirdly, the low-water cutoff failed to function because of the slow descent of the boiler water; fourth, the upper section of the corrugated furnace became exposed. On return of the operator he noticed a change in atmospheric conditions and, in looking into the furnace through the observation port, noticed a section of the furnace near the front overheated and collapsed, Figs. 1, 2. The boiler was immediately secured by shutting off the oil burner, closing the feedwater supply valve and main steam line outlet valve; it was then allowed to cool under natural conditions until an inspection could be conducted.

Inspection Findings

The boiler was first inspected internally to determine the presence of oil or other foreign substance which might cause localized overheating. There was none. Further, the scale was very slight, not being of sufficient thickness to cause overheating of the furnace.

External inspection revealed first that all tubes at the rear had been loosened in their seats. There was, however, no apparent deflection of the tube sheet.

Secondly, the furnace had collapsed for a distance of 67-in. from the front riveted seam to the full extent of the corrugations, and was down 18 in. (see Figs. 1, 2). The width of the bulge, at about the center of depth was approximately 17 in. The entire width of the affected area, though was some 21-in. circumferentially, each way of the top center. There was no apparent thinning of the furnace at the apex of the bulge since the corrugations apparently became sufficiently overheated to permit them, under pressure, to straighten out, but the condition was fortunately discovered prior to burning, thinning and subsequent explosion.

Repair Problems

The construction of the boiler was such that both ends of the furnace were of equal size, thus preventing removal of the defective section without alteration.

Repairs then consisted of cutting away the front tube sheet at the outward turn of the riveted flange to permit replacement of the overheated section with a new section 91-in. in length. A backing-up strip was used at the junction of the welded circumferential seam located at the depth or bottom of a corrugation. The furnace at the front was increased in diameter and welded to the front tube sheet according to Code requirements. All tubes required re-expanding as well as the recaulking of the rivets at the rear of the furnace as well as at the rear head angle braces.

Following repair, the boiler was subjected to 187 psi hydrostatic pressure, proving it to be tight and again suitable for continued service but at a cost of several thousands of dollars.

The Controls

The automatic controls were naturally examined and thoroughly gone over before replacing the boiler in service. It was noted that the function of the low-water cutoff was slow or sluggish under natural evaporation where there was a slow lowering of the mechanism, as would be experienced under natural evaporation. Under a quick blow down, however, or sudden drop of the control float the unit operated instantaneously. There also appeared to be slight binding of the linkage mechanism when slowly operated causing the control to "hang up." It was then concluded that it was not only necessary to blow down the control frequently to remove possible sludge deposits but to also regularly remove and service the control in the area of the linkage as well, so as to be sure that the weight of the float would actuate the control without shock.

The feedwater control valve also required overhaul because of loosening or malfunctioning of parts over a period of a year's operation.

Hand throttling of a feed valve is a difficult method of determining just how much or how little makeup water is required to replace evaporation. If this method is employed, then constant, alert attention is required to prevent accidents due to the possibility of sudden plant steam demands which change water levels without advance notice due to increased evaporation.

The summation of this article serves to again point out the necessity for proper operating controls, the dependability of which can only be brought about by conscientious and proper maintenance of all parts, as well as a regular schedule of blowdown and operational tests.

Philadelphia to Host Air Pollution Control Association Meeting

The city of Philadelphia will be host to the 51st Annual Meeting of the Air Pollution Control Association at the Sheraton Hotel, May 25–29.

Milton Reizenstein, president of the Association, declared that the meeting will bring together many who are today "dealing first hand with air pollution as it affects the health and well being of our nation in this age of power, processes and machines."

Among the eminent authorities who will address the meeting are: The Honorable Richardson Dilworth, Mayor of Philadelphia; Arie J. Haagen-Smit, professor of bio-organic chemistry, California Institute of Technology; William R. Bradley of the American Cyanamid Company, formerly president of the American Industrial Hygiene Association; Morris Katz, consultant to the Department of National Health and Welfare, Ottawa, Canada; and Louis C. McCabe, president of Resources Research, Inc., formerly head of the Los Angeles Air Pollution Control District and now consultant to the United States Public Health Service.

During the four-day meeting a total of more than fifty technical papers covering a wide range of subjects including the challenging significance of surveys on air pollution recently completed in key areas, incineration techniques, basic and applied research on all phases of the air pollution problem.

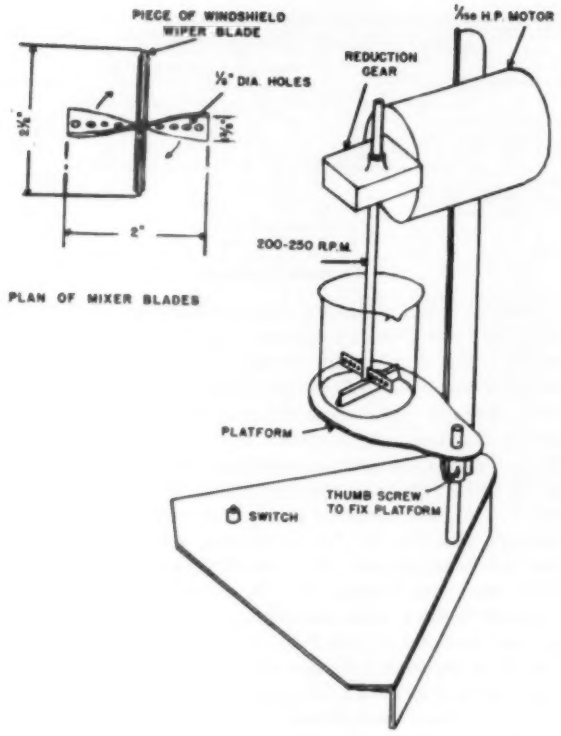


Fig. 1—British Coke Research Assn. laboratory mixer appears in the above sketch for 2–3 oz sample

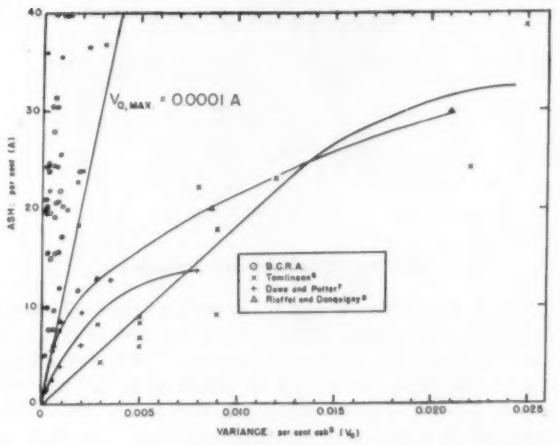


Fig. 2—PComparison of values of sample analyses using B.C.R.A. device as against other samplers

By R. A. MOTT

British Coke Research Association,
London, England

The Reduction of The Errors of Coal Sample-Preparation

The author's organization have been studying coal sampling techniques with a view to improved preparation methods and reduced preparation time. Here is a report on their present practices which result in a limiting variance (sample-division plus analysis) of 0.06.

IN A recent article in COMBUSTION, R. L. Coryell and F. J. Schwerd (1)* emphasized the value of a high-speed mill and of a rotary sample-divider. These they used in a two-stage procedure to reduce the labor involved in, and increase the accuracy of, the preparation of coal samples. They obtained total variances of sample-preparation and analysis not exceeding 0.05 for a coal of about 10 per cent ash, compared with three to five times this value when using the ASTM three-stage procedure. They apparently used a riffle to sample-divide the 3 lb of through-60-mesh coal to the final amount used for analysis and suggested that the slight bias from this procedure could have been removed by the use of a small rotary sample-divider. They referred to a paper (2) published by the British Coke Research Association (B.C.R.A.) but only in respect to a comparatively minor conclusion, and failed to say that their main conclusions support those already drawn by B.C.R.A. The work of B.C.R.A. has, in fact, been recorded in three papers (2, 3, 4). In the present paper, a summary is given of those conclusions on which an improved standard of sample-preparation may be achieved, while saving time in carrying out the operations.

The methods of coal sample-preparation which have been in most extensive use throughout the World during the past 50 years were based on those developed by the Bureau of Mines (B.M.). They must now be considered laborious and subject to bias. By the use of modern high-speed mills and mechanical methods of sample-dividing and mixing it is possible to reduce the frequency of occurrence of rogue results and to eliminate bias, thus ensuring that low variances of sample-preparation are obtained with a great saving of time. Mixing of the laboratory sample is necessary to ensure a low variance of analysis and this will be considered first.

* Numbers in parentheses refer to Bibliography at the close of the article.

TABLE I—VARIANCE ($V_a + V_q$) × 10^4 OF 2-OZ LAYERED SAMPLES THROUGH 65 (TYLER) MESH

Ash, %	B.C.R.A. Lab. Mixer (1 min)	Quickmix (2 min)	M.B. Mixing Wheel (20 min)
10	10	34	328
15	7	80	903
20	29	8	863
30	12	36	2830
37	4	66	678
Mean	12	45	1120

TABLE II—MINIMUM WEIGHTS OF SAMPLE (W) FOR DIFFERENT VALUES OF UPPER SIZE (S_2) AND FREE ASH (a), FOR SPECIFIED LIMITS OF VARIANCE OF SAMPLE-DIVISION

Upper size, S_2	Total ash (= a + 4 per cent) 6	10	15	20	30 and over
1st stage sample-division: W (lb) for variance of 0.025					
3 (Tyler) mesh	4	12	19	25	31
4 (Tyler mesh	2	5	8	11	13
8 (Tyler) mesh	1/4	3/4	1	1 1/2	1 3/4
2nd stage sample-division: W (lb) for variance of 0.015					
14 (Tyler) mesh	1/4	3/4	1 1/4	1 1/2	2
35 (Tyler) mesh	1/4	1/2	1/2	3/4	1
65 (Tyler) mesh	1/4	1/4	1/4	1/2	1/2

Mixing of Laboratory Samples

The B.M. Mixing Wheel (5) is perhaps the best known device for the mixing of laboratory samples of coal, but since the final stage in the preparation of samples according to the B.M. procedure is crushing in a ball mill, which is itself a good mixer, an erroneous idea of the value of this device is probably common. In fact, its motion is too gentle to give effective mixing of layered samples of coal and shale (the most severe test). In Table I a comparison is given of the variance of quarters of 2-oz samples (variance of analysis, V_a, plus variance between quarters, V_q) after mixing in the B.C.R.A Laboratory Mixer (3, 4), the B.M. Mixing Wheel and the "Quickmix" (a hand-shaking device). Layered samples were used in these tests, the proportions of coal and shale being adjusted to give a series of high values of the ash. It will be seen from these data that the B.C.R.A. Laboratory Mixer is superior to both of these devices.

The B.C.R.A. Laboratory Mixer is illustrated in Fig. 1. Its value lies in the vigorous motion and in the fact that the bottom of the container is scraped. Fig. 2 compares values of the variance of analysis obtained with its use with values reported in the literature (6, 7, 8). It will be seen that, using the B.C.R.A. Laboratory Mixer, the variance of analysis need not exceed the limiting value:

$$V_{a,\,max} = 0.0001A$$

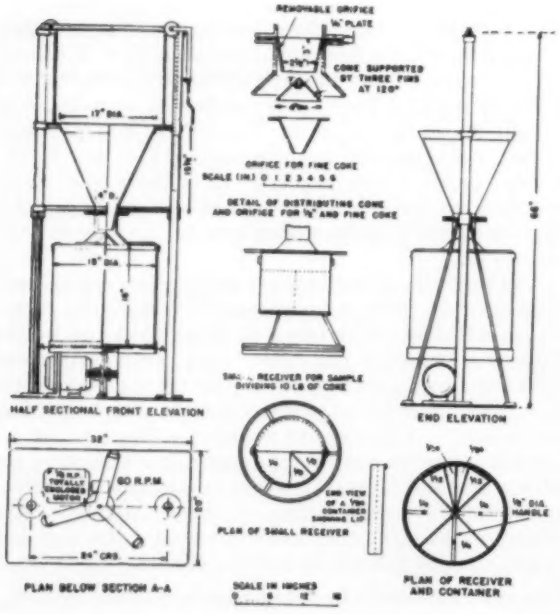
where A is the ash percentage.

Sample Division

The B.C.R.A. Rotary Sample-Divider (R.S.D.) is used for three levels of capacity, as illustrated in Figs. 3 and 4. Fig. 3 shows the design "(Large") in which the receiver will hold 75 lb of coal through 1/4 in. or 50 lb. of coke through 5/8 in., and the modification ("Medium") for 15–20 lb of coal or coke. Fig. 4 shows the "Small" R.S.D. with a capacity of about 3 lb of fine coal or coke. In all forms, the base rotates at about 60 revolutions per min. The base carries a receiver in which containers of suitable fractions of the total area are placed. These containers are clipped to a diameter plate in the receiver of the Small or Medium R.S.D.; in the Large R.S.D. the receiver is filled with suitable containers. (With 75 lb of coal in the Large R.S.D., a 1/24 fraction is approximately 3 lb; with 3 lb of coal in the Small R.S.D., 1/16 fraction is 3 oz). In all cases, the coal or coke is discharged from a hopper over a fixed distributor cone into the rotating receiver and its containers.

Since the rate of rotation is 60 revolutions per min and the time of efflux is designed to be one minute for all particle-sizes, the sample is taken by 60 increments. It is the taking of a sample by a large number of increments which reduces the variance between different containers to a low value.

In experiments on the use of the R.S.D., the use of "nests" of containers gives a good foundation for calculating the variance of sample-division. Fig. 5 summarizes the results of a large number of experiments to de-



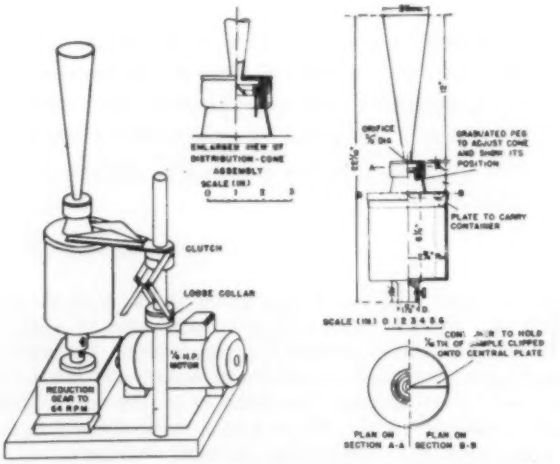


Fig. 3—B.C.R.A. rotary sample divider (RSD) serves three capacity levels; large, for samples up to 75 lb of coal; medium, for samples of from 15 to 20 lb of coal. See also Fig. 4

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Fig. 4—The small RSD, above, handles samples of about 3 lb of fine coal or coke. This model and those in Fig. 3 rotate at about 60 rpm

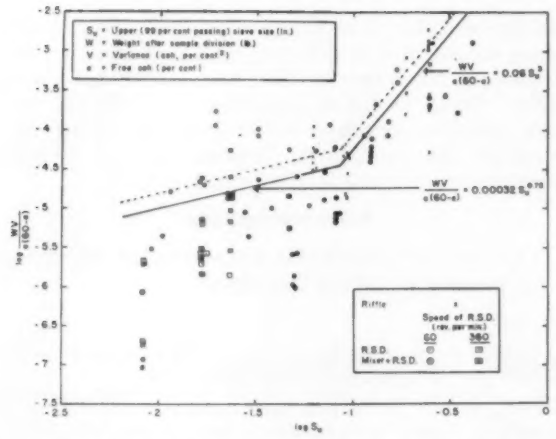

Fig. 5—The effect of particle size and weight after sample division upon variance is summarized here

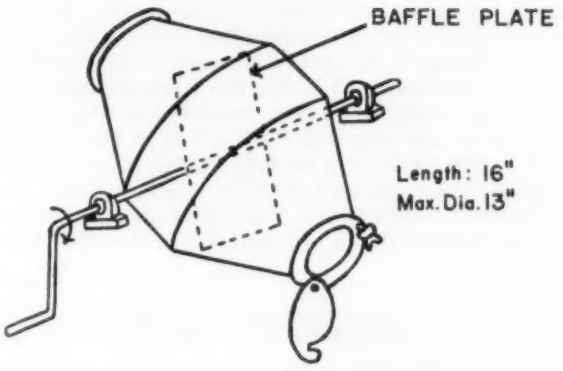

Fig. 6—Double-cone mixer, such as the above, is used where vertical segregation may bias results

termine the effect of particle-size of coal, ash, and weight after sample-division on the variance. (In some experiments the R.S.D was run at 360 rev./min.) The denominator of the function plotted on the ordinate takes account of the fact that the variance increases with the free ash up to a certain level (about 30 per cent) and then falls; the numerator takes account of the fact that the variance increases with decrease in the weight to which the sample is reduced. The following conclusions may be drawn.

(1) The variance decreases rapidly with decrease in S_u (the upper size of the coal) to about 8 (Tyler) mesh (thereby confirming the conclusion of E. G. Bailey (19)).

(2) With further decrease in S_u the variance decreases more slowly, but reduction of particle-size is an obvious method of ensuring a low variance.

(3) Increase in the number of increments by which the sample is taken helps to ensure a low variance.

From the equations to the firm lines (which, by excluding a few points, eliminate undue influence by a small body of data) Table II can be constructed to give the minimum weights of sample (W) for different values of S_u and of the ash ($a + 4$) to ensure a total variance of these two stages of sample-division of under 0.04. Such values refer to the use of rotary sample-dividers (and particularly of the B.C.R.A. R.S.D. with which most of the experimental evidence was obtained)

Mixing During Sample-Preparation

The use of high-speed beater mills is the most satisfactory method of crushing a large sample of coal rapidly and such mills have the advantage that, unlike mills of slower speed, they are not very sensitive to the presence of shale, so that it is easy to standardize a screen outlet which will give a "99 per cent through" size for a wide range of coals.

It should be noted that the weight of coal inside the mill at any one time is small, so that if the coal is segregated (in terms of ash) before feeding it will still be so after crushing. The conclusion of Coryell and Schwerd (1) that mixing of the final sample is not necessary when pulverized in a high-speed mill is, therefore, not generally valid; it may be true if the coal fed to the mill is not segregated, and the segregation of a coal of 10 per cent ash, such as they used, may not be great. Good mixing can only be achieved by treating all the coal in one container at the same time, a matter of some difficulty with a sample of 1 cwt. Fortunately, the use of an R.S.D. usually overcomes the necessity for mixing before sample-division. An R.S.D. is not a mixer but it *is* a uniform distributor, so that, although the coal in any container may be segregated in a vertical plane, there should be no segregation between containers. If second-stage sample-division is carried out with an R.S.D., this "vertical segregation" is of no importance, but if it is carried out with a riffle the result may be biased. In the latter case, then, after sample-dividing to the quantity allowed in Table II, the sample should be crushed to pass a 65-mesh (Tyler) sieve and mixed in a mixer such as that shown in Fig. 6. It has been found that this "Double-Cone Mixer," rotated by hand at about 60 revolutions per min., gives adequate mixing of 0.5, 2 and 8 lb of through-65 (Tyler)-mesh coal in 1, 2 and 4 min, respectively.

Having obtained a sample of $^1/_4$ or $^1/_2$ lb of through-65 (Tyler) mesh size, the analysis sample, conveniently of 2 oz, is readily obtained by sample-division in the Small R.S.D. By prior mixing in the Double-Cone Mixer, the variance of this stage can be limited to about 0.0020.

Though the specified variances of Table II should be attained without mixing (when using R.S.D.'s), the introduction of a mixing stage will always tend to reduce the variance. B.C.R.A. is making a general study of the use of mixers and has had considerable success with a "Twin Single-Cone Mixer," which will be described in a later communication. The introduction of such mixing stages may be desirable only for special work, such as the determination of the thermal efficiency of a power-station boiler, though mixing before the final sample-division (to 2 oz) is always desirable.

Conclusion

Rotary sample-dividers have been shown to be superior to riffles by R. C. Tomlinson (6). The use of the B.C.R.A. R.S.D. (Large, Medium and Small) greatly facilitates the attainment of low variances of sample-division, even for high-ash coals, and enables a 75 lb sample of coal to be reduced to 3 lb in the first stage (after crushing to 4 or 8 (Tyler) mesh) and to 2 oz in the second

and third stages (the third stage being at 65 (Tyler) mesh, the second at 14 35 or 65 (Tyler) mesh). By suitable mixing, as previously described, the contribution of the third stage to the total variance can be kept very low. If a sample exceeds 75 lb, the first stage can be carried out in two steps, the product then being mixed in a suitable mixer and sample-divided to 3 lb in the Medium R.S.D. (the mixing and the high relative value of W obviating the consideration of this as a further stage). For a sample of small weight or low ash, two stages will often suffice, the first (to up to 2 lb) being at 8 (Tyler) mesh and the second (to 2 oz, after mixing) at 65 (Tyler) mesh. Using the B.C.R.A. R.S.D., the total variance of sample-division in these two or three stages need not exceed 0.042. Using the B.C.R.A. Laboratory Mixer, the variance of analysis for ash should be of the order of only one-tenth of this, so that the limiting variance (sample-division plus analysis) may be stated as 0.05.

Acknowledgement

I am grateful to the British Coke Research Association for permission to publish this paper.

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New Power Test Codes Available

Three new power test codes have been published by The American Society of Mechanical Engineers, the Society recently announced. They cover fuels for diesel engines and heat generation, deaerators and water-cooling equipment.

The 84-page "Test Code for Diesel and Burner Fuels" contains methods for the collection of samples and the determination of all physical and chemical properties for the value of liquid fuels when they are used to generate heat or power. Gasoline or other fuels used in spark ignition engines are not included, however. The Code contains a new feature—the introduction of each test method by a brief discussion of the significance of the test.

The new "Power Test Code for Deaerators" was necessitated by failure to achieve plant operating savings and to halt corrosion by including the deaerating section in the main condenser in power plants, said a spokesman for the code preparation committee. Other standards such as "Method of Testing for Dissolved Oxygen in Industrial Water" and "Standard Methods and Procedures for Determination of Dissolved Oxygen" were referred to and the new code is said to be in substantial agreement with them.

A departure from the usual test code design is made in the "Power Test Code for Atmospheric Water-Cooling Equipment." While other standards give weight towards a theoretical justification of methods recommended, this code is designed to guide the field engineer testing the equipment. Two reasons are given by the Power Test Code Committee for this change: conditions of performance on which guarantee is based cannot be duplicated at will or held constant during the test and simple analytic expressions which would permit reduction of test conditions to guarantees are not available.

The codes may be ordered, separately or together, from: Order Department, The American Society of Mechanical Engineers, 29 West 39th Street, New York 18, New York. Prices are: Diesel and Burner $4.00; Deaerator Code, $3.00; Atmospheric Water-Cooling Equipment Code, $2.75.

Continuous Steam-Turbine Blading-Tests

A continuous test program to obtain more performance data on current blade designs is being conducted in a modern experimental turbine laboratory at Allis-Chalmers' West Allis Works.

Included in the laboratory, which is also being used in conjunction with other test facilities and with theoretical analysis in the development of new blade designs, is an experimental turbine with its dynamometer equipment.

Air was selected as a working fluid for the turbine because the laboratory air-supply system makes the laboratory independent of other facilities except for a source of electrical power. Air supply to the turbine is furnished by an 8500-rpm, three-stage centrifugal compressor equipped with adjustable, inlet guide vanes driven through a speed-increasing gear by a 1250-hp induction motor.

Air has additional advantages in that it very nearly obeys the perfect gas laws at atmospheric pressures and moderate temperatures, thereby making the calculations of test results easier than if steam were used. Air does not present the condensation problems that occur with steam.

In some respects, construction of the experimental turbine is similar to that of commercial steam turbines. The blades are made of 13-chrome steel inserted in standard tee slots in the spindles and cylinders. Disks, blade drums and balance pistons are shrunk on the shafts so that they can be removed if necessary. Frequent removal is not contemplated, however, because four complete spindles are available and can be rebladed without removing the disks or drums.

American Power Conference in Review—I

The twentieth annual meeting of the American Power Conference was again held at the Sherman Hotel in Chicago, March 26–28 inclusive. Registration was excellent with some 2800–2900 signing in.

Steam Turbines

C. W. Elston, General Electric Co., in his paper "First Large Steam Turbine for Operation with a Boiling Water Reactor" presented a design description of the 192,000-kw, tandem-compound, double-flow steam turbine being built by the General Electric Co. for the Dresden Nuclear Power Station. Available published information indicated that radioactivity would not have a significant effect on turbine materials. Erosion and corrosion were considered the primary problems with the effect of the presence of an inordinate amount of oxygen in the steam being the major unknown.

The overall concept of the turbine and many of the design details followed these precepts:

1. The quality of the steam expanding through the turbine should be maintained within the range of successful past experience by the use of suitable moisture separating devices self-contained within the turbine.
2. Stage energy and pressure drops in the high-pressure portion of the steam expansion should be considerably less (approximately one-half) than that commonly used on modern turbines designed for conventional steam conditions.
3. Internal wiredrawing-type leakage paths ordinarily unimportant in normal steam turbine design practice should be eliminated to the greatest practical extent.
4. Where impossible to eliminate such leakage paths, the surfaces forming the leakage path should be faced with erosion resistant materials deposited by welding, a practice unnecessary and uneconomical in conventional turbines.

The Dresden turbine is designed to produce a generator output of 192,000 kw at 2.5 in. Hg absolute exhaust pressure while heating the condensate, and $^1/_2$ per cent makeup to 405 F in five stages of feedwater heating. Under these conditions, the primary admission is at 950 psig, 540 F, and the secondary admission at 460 psig, 462 F. As load and secondary flow are simultaneously reduced, the secondary admission pressure rises to approximately 1000 psig at zero secondary flow.

The turbine unit is an 1800-rpm, tandem-compound, double-flow, three-casing design connected to a 245,500-kva generator which has conventional hydrogen cooling. The 15-stage, opposed-flow, high-pressure turbine section exhausts through two crossunder pipes at about 180 psia to a 7-stage, intermediate-pressure section. The intermediate section exhausts at about 11.5 psia through a large rectangular crossover to a 3-stage, double-flow, low-pressure turbine section with 38 in. last-stage buckets. The exhaust hood forms a single-condenser connection.

In addition to the normal compound governing system, there are numerous special and emergency protecting features. One interesting feature is the use of two turbine vacuum-trip mechanisms. These trips operate when the vacuum falls below three different set points. The first trip setting, in a range of 20–25 in. of mercury vacuum, scrams the reactor and trips the secondary admission valves. The second, which is set in a range from 15–20 in. of mercury vacuum, trips all the turbine stop and admission valves. A third trip point, set at approximately 7 in., trips the sphere isolation valves.

Although commercial operating experience will be required for confirmation, the experience gained in designing this turbine, the author stated, indicates that large steam turbines, designed for the unusual conditions imposed by a boiling reactor, are practical. Such turbines, although presently more costly than comparable turbines for conventional steam conditions, should have satisfactory reliability and freedom from maintenance.

E. P. Hansen, A. C. Holmes and **J. J. Fleischmann** joined forces on the paper "High-Temperature Steam Turbine Design Improvements from Operating Experience." They quickly pointed out that over 75 per cent of turbines installed in the last 10 years are in the high-temperature, high-pressure category and are in ratings of 75,000 kw and higher. While the fundamental purpose of the higher temperature is to gain thermal efficiency, the problem faced by designers is to maintain the high efficiency throughout the turbine's life and to provide many years of reliable service.

This design problem divides into three important considerations: (1) high-temperature stress levels, (2) effects of temperature gradients and (3) high-temperature

oxidation. These factors were very briefly discussed.

With the advent of steam temperatures in the 1000 to 1050 F range, the authors reminded the audience, the bolting problem became increasingly difficult. So much so that designs and practices have had to undergo progressive refinement. Substantial reduction in permissible stress levels and more precise evaluation of stress patterns as affected by temperature transients have become necessary. Use of some of the "standard" materials which had excellent service records at the lower temperatures had to give way to changes to other materials which are less vulnerable to temperature effect.

The useful life of a bolt can be related to some value of permissible limiting strain. Initial tightening levels have all had to come under a more rigid scrutiny. The adoption of lower initial tightening stresses results in a less rapid expenditure of the available plastic strain during each relaxation period. Thus, more economical use of the "strain life" in the bolt is achieved.

Among designs adopted in recent years replacing the bolted type are breech-block pressure-seal closures now applied to all new design, high-pressure valves, where steam temperatures are 1000 F and higher. Bolted flange assemblies also have given way to fully welded joints in high pressure steam lines subjected to rapidly fluctuating temperatures.

The turbine designer's most practical means of minimizing thermal stresses is by separating the fastest heating sections and parts of different temperature to allow unrestrained expansion of these parts and by avoiding excessive metal thickness.

The results of an investigation of these problems culminated in the design and testing of a ring-type nozzle chest, which was first placed in service in 1956. This nozzle chest retains the necessary feature of isolation from the casing to allow free expansion and avoid thermal-stress cracking of casings, and also permits desired improvements over the individual chests.

The elimination of the integral valve chest on the casing in favor of separate steam chests for all units with 1000 F or higher initial steam temperature is another factor in thermal stress considerations of the high pressure casing.

The authors similarly discussed other problem points such as distortion, inner casing construction and offered current solutions.

Deaeration Panel

R. M. Lemen, The Permutit Co., led off the panel with the paper "Deaerators—Manufacturer's Viewpoint." There are three basic types of systems, Mr. Lemen explained, in which oxygen removal can be accomplished. One is the completely closed system with surface condenser hotwell deaeration. Another is the partially closed system with an open direct contact deaerator in the system serving as one of the stage heaters. The third is the completely open system where all of the stage heaters are direct contact heaters. These he proceeded to describe in some detail with illustrations to reported experiences with each.

The seriousness and destructive force of corrosion in boilers and preboiler circuits warrant the adoption of the best corrosion control methods available. An attempt was made to emphasize the advantages of employing an open direct contact deaerator in central station feedwater system so as to give the most complete removal of oxygen and free CO_2, and also to provide insurance for removal of any gases admitted to the feedwater through air leakage or contained in heater drips. Such provisions will afford protection against attack of equipment beyond the deaerator, but the equipment between a standard surface condenser and the deaerator may be subjected to attack. Consequently, many plants employ surface condenser hotwell deaeration in addition to an open direct contact deaerator as a stage heater.

R. A. Wilson, Allis-Chalmers Mfg. Co., followed with his paper "System Deaeration in the Condenser Hotwell a Manufacturer's Viewpoint." Mr. Wilson contended that the modern steam condenser has established itself as an excellent piece of deaerating equipment. Under favorable conditions it is probably as good as any available deaerating equipment. Its theory and practice as such is soundly established and has been thoroughly demonstrated. The author stressed, however, that condenser deaeration is performed under vacuum and that good results can be completely nullified by a small amount of air leakage into the deaerated condensate.

Considerable emphasis needs to be put on design and operating details. Some operating practices, such as controlling air leakage, are actually necessary for other reasons than deaeration. The author mentioned he was not impressed by any argument that all the operating details he favored could be neglected if the deaeration is done under pressure. This appeared to him to be uneconomic and unsound.

Good condenser deaeration he maintained is much simpler to achieve than is generally thought by plant operators. It has been demonstrated by hundreds of condensers of different manufacture and design under all sorts of operating conditions. Most all condensers are capable under reasonable circumstances of better performance than they were guaranteed to produce. This is reasonable and is to be expected.

As a result Mr. Wilson felt, where it is thought desirable, many plants can be built at a saving and operated with appreciable advantage, without deaerators, with comparatively little operating hazard. This does require a very realistic appraisal and perhaps a little more interest and alertness in design and operation than with the extra pressure deaerator.

H. A. Grabowski, Combustion Engineering, Inc., offered his paper "Deaeration—Boiler Manufacturer's Viewpoint" next. The selection of a deaerating method fixes, to a degree, the potential for corrosion in the preboiler and boiler circuits. Since corrosion and the effect of corrosion products constitute a major problem in the generation of steam at high pressures, it is logical that a boiler manufacturer would have a direct interest in the selection of apparatus for the removal of oxygen. Designers of power plants, including consultants and engineers at utilities, select the method for removing dissolved gases from condensate. The boiler maker's contribution to the program, in Mr. Grabowski's opinion, is to describe from numerous plant studies the performance characteristics of systems employing deaerating heaters and deaerating condensers.

A partial answer to the question of efficiency of the

two deaerating methods was offered by the author on the basis of field studies completed by his company with the cooperation of various utility organizations. Twenty systems, ten of both deaerating methods, were selected for this review. The oxygen data were obtained by the use of a continuously recording Cambridge analyzer. The test results were arranged to establish the oxygen content in the water delivered to the boiler at (a) normal operation, (b) low load operation and (c) startup and banked operation. These data were evaluated to determine if the oxygen results were influenced by (1) the addition of heater drips to the condensate, (2) the addition of condensate from storage or surge tanks to the system and (3) the addition of evaporated or demineralized makeup water to the cycle.

The systems investigated covered a range of pressures from 900 psig to 2600 psig and steaming rates from 500,000 to 1,000,000 lb per hr. Summaries were given of the equipment and the cycles for the two sets of ten study cases.

The author stated his company's data from over thirty boiler-turbine combinations, twenty of which were mentioned in this presentation, indicated a need for increasing the range of operation of deaerating heaters and deaerating condensers to prevent the introduction of oxygen during low load, banked and startup operation. A low potential for oxygen in a system is possible only when the deaerating method and the preboiler design of heaters and piping receive an equal measure of attention. Excellent results can be obtained with both deaerating heaters and deaerating condensers.

A deaerating condenser designed in a preboiler circuit to exclude contamination provides an assurance of a low level of corrosion due to oxygen. To be effective Mr. Grabowski believed attention should be focused on the following:

1. Prevent the addition of low-pressure heater drips into the condensate line downstream of the condenser.
2. Prevent the addition of undeaerated makeup into the condensate line.
3. Maintain oxygen removal efficiency at low loads.
4. Monitor the inleakage of air through piping downstream of the condenser.

A deaerating heater, when properly designed, assures a minimum of corrosion downstream of the heater. Unfortunately, in most instances, less attention to oxygen removal upstream of the high-pressure heaters is applied when there is a final oxygen removal apparatus. The latter surfaces are most vulnerable to corrosion. Here again Mr. Grabowski urged that attention should be given to the following when applying deaerating heaters:

1. Maintain a positive and constant deaerator pressure.
2. Size the heater to offset temporary upsets such as those following evaporator cracking periods.
3. Deaerate evaporator makeup water.
4. Direct low-pressure heater drips to the condenser at low operating loads.
5. Prevent the addition of undearated water to the condensate line upstream of the deaerator.

The data, the author concluded, indicate that the corrosion potential is influenced to a greater extent by what the plant designer does than the ultimate good which a manufacturer of a deaerator can achieve. Stopping corrosion and hence boiler outages should not be controlled by small Btu saving schemes. The savings gained in piping, pumps and a small thermal gain can be offset by large outage costs when means are not incorporated to prevent corrosion from low-load or banked operation.

John K. Bryan, Union Electric Co., supplied a paper on #Deaerators—The Operator's Viewpoint." From an operator's viewpoint, a deaerator is a tool, one of several available to him, for minimizing costly corrosion of the feedwater heating equipment and of the boiler itself. It is a tool that must be used with care, because its stored energy and stored water can wreck a turbine-generator. It is a tool that must be maintained, because parts of the deaerator itself are subject to corrosion and maladjustment.

Mr. Bryan expressed the feeling that his company's viewpoint on deaeration is probably best summarized by plans of a 300 Mw unit now being engineered. The condenser will feature a deaerating-type hotwell, from which they expect no more than 0.01 cu cm per liter oxygen content. Drips, drains and vents will be handled carefully to minimize their contribution to contamination. Half-way through the cycle there will be a deaerator, designed to operate at 120 psia with full load on the main unit. At reduced loads, the pressure of the extraction steam supplying the deaerator decreases, but is nevertheless above atmospheric pressure all the way down to minimum load (20 per cent). Such a deaerator can be vented to atmosphere under all operating conditions. It is to be expected that there would be no more than 0.005 cu cm per liter oxygen content in the feedwater leaving the deaerator. An oxygen recorder, located in the central control room, will monitor the cycle.

Chemical removal of oxygen in feedwater, cost of chemicals, cost of labor and cost of technical supervision are all appreciable, along with the possibility of undesirable chemical side reactions so that Mr. Bryan's company hopes to avoid this cost and complexity by use of a deaerator in the feedwater heating cycle.

A. M. Guy, Southern Indiana Gas and Electric Co., then contributed his paper "Condenser Hotwells—Operator's Viewpoint." From an operator's view, one of the principle disadvantages of a condenser hotwell deaerator system is that each and every condenser or hotwell opening or attachment is a potential source of air inleakage. These include such items as hotwell level controller, sight glasses, level alarms, drain inlet connections, man holes and numerous other piping joints and valve packings. In spite of the fact that most of these connections now days are welded, numerous air leaks as a result of these are invariably present.

Another serious disadvantage to condenser-hotwell deaeration as compared to thoroughfare or deaerating heater type of oxygen removal is that space limitations and capital investments generally fix the storage capacity of the hotwell, and do not always allow the capacity most desirable for widely fluctuating plant surges. It is extremely difficult to build into a hotwell all of the surge capacity which may be designed into a deaerating heater.

Mr. Guy acknowledged a reluctance to make a bold face statement to the effect that more complete oxygen and/or carbon dioxide or other gas removal may be effected by a deaerator heater in the system than can be accomplished by main condenser and hotwell deaerator

methods. There were, he felt, too many variables affecting these factors. It appeared to him, however, to be more feasibly economical to remove oxygen and other gases that may be present in 28 or more inches of vacuum than to do it at 40 or 60 or 100 psig or more.

A major advantage to condenser and hotwell deaeration as Mr. Guy sees it is that all of the feedwater cycle rather than only a portion of it is benefited by low oxygen water. The main condenser deaeration if effective in reducing the oxygen content to a low value means that all of the low pressure feedwater heaters as well as such other equipment as inter and after coolers, gland steam condensers, condensate pumps and other installed heat exchange apparatus, will be in contact with low oxygen content water. This is especially beneficial when making a determined effort to reduce to the lowest possible value the iron and/or iron oxide entering a boiler from the preboiler cycle.

Another principle advantage for condenser hotwells is that they may serve to simplify the steam water cycle of a plant by eliminating one or more pieces of equipment. Such things as feedwater heater drains, gland steam condenser drains, inter or after cooler drains, steam and water conductivity sample drains and numerous other items of high quality water may very readily be returned to the system directly into the upper portion of the hotwell or main condenser without the use of heater drain tanks and their attendant level controls and alarms or heater drain pumps with all of their appurtenances. Further, some of these drains may well contain moderate or large amounts of sensible heat which is often used as reboiling heat in the upper portions of the hotwell in order to assure more complete deaeration throughout the early stages of the preboiler cycle. This, Mr. Guy stated, points out the way for using the hotwell as a low pressure flash tank which might well reduce the required equipment and piping in a central station. However, a high pressure flash tank may still be required.

Another point the author advanced in favor of condenser hotwells with respect to operation is that they can be so designed to give several minutes more of condensate storage for condensate pump protection than is usually available when thoroughfare deaeration is employed. When one of these outsized hotwells is attached to the condenser it can readily be used as a surge tank to provide the required volume of water for standby capacity during startup, shutdown or the low load periods when condensate pump recirculation is desirable. Moreover, Mr. Guy pointed out that during these periods especially, it is desirable to recirculate and utilize deaerated water which can be provided by means of main condenser deaeration, a feature not normally available if the system relies upon thoroughfare deaerators as the principle means of reducing the oxygen in the boiler feed water.

W. R. Steur, Sargent & Lundy, wound up the panel with his paper "Deaeration—Design Engineer's Viewpoint." Since we are now able to measure oxygen fairly accurately, by chemical and physical methods, Mr. Steur submitted, he believed it would be a logical step to define acceptable limits of oxygen content in condensate, as has been done for silica and dissolved solids in boiler water.

Commercial condenser deaerators are available which have an oxygen guarantee in the condensate leaving the hotwell pump of 0.01 cu cm per liter. The deaerating heater having a guarantee of 0.005 cu cm per liter on the other hand makes the equipment not directly comparable since their performances are not on the same basis. The condenser deaerator is a curious combination for it is in one of the principal sources of oxygen contamination. While it has been pointed out that condenser deaerator installations have been tested and found to give oxygen contents considerably below their guarantees, the author stated, it must be noted in examining the results of these tests certain conditions must obtain, and this is undoubtedly the reason the manufacturers in making a 0.01 cu cm per liter guarantee require certain conditions to be observed. These are that the equipment be operated at or above 50 per cent load, that the circulating water temperature shall be 50 F or more and that the location of all drips, drains and makeup connections be located as specified by the manufacturer.

The reason for this variation appears to be largely in the problem of air removal since most modern condensers are so designed that fairly effective reheating of the condensate is obtained, thus eliminating the condensate temperature depression which would preclude effective oxygen removal. If either load or circulating temperature decrease in value, the condenser produces a correspondingly improved back pressure. Since the quantity of oxygen and undissolved gases to be removed remains the same, the air removal equipment must therefore handle larger and larger volumes as the back pressure is decreased. What happens in a typical condensing installation is that the air removal equipment reaches its cutoff point and thereafter requires a virtually constant condenser pressure to remove the air. The effect of this is to increase the partial pressure due to the oxygen in the condenser steam space which results in a higher oxygen content of the condensate leaving the equipment.

The condensing equipment has the further disadvantage, apart from part load performance, that on starting up, a considerable volume of air is contained in the steam space and numerous instances have been cited of the difficulty of removing the resulting oxygen contamination from the system. Unless special recirculating equipment is provided, the effect of this initial contamination at startup can persist for several hours.

In considering the deaerating heater, the effect of cost was presented in tabular form. Further consideration was asked for the improved cycle performance obtained by having a direct contact heater in place of a closed heater. The effect of eliminating the thermal difference, Mr. Steur explained, generally results in a lower heat rate by 0.8 per cent. In the case of larger units, this can amount to a considerable yearly gain and was held to be definitely to the advantage of the deaerating heater. In studies made at various times reflecting this factor, it has generally been shown that the effect of this thermal gain cancels any increased cost for the deaerating heater equipment. If a dollar value is given for the advantage of having a source of emergency suction condensate, the author felt the advantages became more in favor of the deaerator.

Mr. Steur commented that it was in the matter of performance that the deaerator held the edge. The deaerating manufacturer guarantees 0.005 cu cm per liter which is substantially better than that available with the current designs of condenser deaerators.

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Fourth Nuclear Congress Convenes in Chicago

The 1958 joint meeting of the Atomic Energy Management Conference, the Sixth Hot Laboratories and Equipment Conference and the Fourth Nuclear Engineering and Science Conference known as the Nuclear Congress was held in Chicago, March 17–21 inclusive. As in previous years the Management Conference sponsored by the National Industrial Conference Board and the Atomic Industrial Forum confined its activities to the first three days of the meeting and held all its sessions at the Palmer House. The 29 sponsor organizations for the Nuclear Conference scheduled their sessions along with the Atom Fair at the International Amphitheater. The Hot Laboratories Conference opened their part of the program Wednesday, March 19, and closed it March 21 at the International Amphitheater. As could be expected there were many papers (22) at the Nuclear Conference alone, so that we abstract below only a very small number which we feel may be of direct interest.

Pumps

C. H. Gabbard, "Diaphragm Feed Pumps for Homogeneous Reactors."

High pressure low capacity feed pumps are required in homogeneous reactors to return the fuel solution to the high pressure system and to provide purge water to the pressurizers and to the circulating pump motors. The author discloses problems encountered in the development of a 1.5 gpm diaphragm pump for the Homogeneous Reactor Test. These problems pertain mainly to the development of suitable check valves for water and uranyl sulfate, and to the development of suitable diaphragms for long term service. Paper No. 74.

W. M. Wepfer, "Guide to the Selection of Canned Motor Pumps."

This paper describes the questions most often asked by prospective buyers of canned motor pumps, discusses briefly the problem and presents answers to the questions. Some typical subjects discussed are starting considerations, power required for cold water pumping, cooling water requirements, emergency and standby conditions. Curves showing normal values for the data are included. Paper No. 77.

O. P. Steele, III, "High Temperature Mechanical Canned Motor Liquid Metal Pumps."

Nuclear aricraft studies and the desire for superheated steam and other nuclear power plants have placed emphasis on sodium and sodium potassium alloys as high temperature heat transfer mediums. After careful consideration of all various pumping problems for handling these materials, a mechanical canned motor pump was considered to have the greatest success potential. The design problems and their solutions are outlined in this paper. Pumps of this type are now in production in sizes to 700 horsepower and for stream temperatures to 1600 F. Paper No. 76.

C. E. Miller, "Operation of 3000-GPM Sodium Pumps."

This report summarizes the principles of operation, the actual performance characteristics and the operational problems encountered with the 3000-gpm sodium pumps for SIR, and the means taken to solve the problems. Paper No. 183.

J. C. Fox, "Design of the Reactor Piping and Pressure Tubes for the PRPR."

The PRPR will be the first reactor designed for power recovery to use a pressure tube design. Reasons for the selection of this type of design are presented, and its advantages and disadvantages for this application are reviewed. Unique features of the PRPR core are described and some design problems are outlined. The zircaloy process tube design and fabrication program are discussed extensively. Information is also given on the component development and testing program now in progress to establish some of the final design details. Paper No. 189.

A. J. Martenson, J. S. Busch and **C. F. Peck,** "Shock Analysis of Pressurized Water Reactor Core Suspension Systems."

The LMFRE reference reactor has been designed as an experimental, two region, externally cooled reactor utilizing a solution of uranium dissolved in bismuth as the side reflector coolant. Moderator material is reimpregnated graphite in both the core and reflector regions. A power level of 20 MWH has been selected for design purposes. Experimental ports are incorporated in both the side reflector and the core, and overhead control rods are provided for nuclear safety. Paper No. 201.

J. Pickel, "Code Problems in the Design of Nuclear Power Plants."

This paper discusses the difficulty of designing the various components of a nuclear power plant, strictly in accordance with the appropriate code. In conclusion, it is recommended that a unified code for nuclear systems be undertaken. Paper No. 79.

V. T. Malcolm and **S. Low,** "Inspection and Testing of Pressure, Piping as Related to Nuclear Power Plants."

At this time much progress is being made in the applications of nuclear energy for ship propulsion and the generation of electric power. This progress has accelerated efforts toward obtaining standard practices for inspection and non-destructive testing of piping and its components on a comprehensive basis, as it is felt that many of the current specifications are somewhat unrealistic and are the prime cause for the exorbitant cost of nuclear energy as such specifications attempt to provide insurance against any and all contingencies. Many engineers feel that such rigid requirements are unnecessary and fail in their intent because frequently the desired effect obtained by certain ones is canceled by another. However, there is no doubt that many unusual hazards exist from radioactive containment and that these hazards require extra precautions is a valid one. Paper No. 132.

D. J. Santeler, "Leak Tightness Inspection of Nuclear Power Plants and Their Components."

The problem of a standard reference to which gas flows can be compared as well as the associated problems of undirectional leaks, pressure and temperature dependent leaks, real versus virtual leakage and leakage conversion to different pressure or fluid conditions is discussed in this

paper. In addition, a few of the methods of leak detection, their sensitivities and their limitations are described and the need for standards in defining sensitivity and minimum detectable leakage is brought out. Paper No. 200.

J. F. Harvey and **R. M. Douglass,** "Advancing Nuclear Component Design by a Construction Code."

The special design and operating considerations imposed on nuclear components have pinpointed the merit of judiciously utilizing pressure vessel materials without jeopardizing them by poor construction details. However, the first prerequisite of this procedure is a code of construction requirements to insure adequacy, safety and a common basis for standardization. This common basis will permit the maximum use of the physical properties of the construction materials and the use of many standard, simplifying or cost-saving methods of manufacture. The purpose of this paper is to present the construction problems and the detail requirements that the nuclear construction codes must consider. Paper No. 214.

Operation

R. H. Jones, T. E. Lempges, H. J. Williams and **J. Wooton,** "Operating Experience and Results of Testing the First APDA Prototype Liquid Metal Once-Through Steam Generator."

A prototype reactor plant once-through steam generator, consisting of seven full-length $\frac{1}{2}$ in. OS. × 0.050 in. wall single-wall tubes, was tested for a period of about one year to determine its steady-state characteristics and its transient behavior. The experience gained in the year of operation and the result of the various phases of the tests are presented. No number.

L. E. Glasgow, J. E. Owens and **D. H. Johnson,** "Start-Up and Operation of the Sodium Reactor Experiment."

The dry subcritical and critical tests are outlined. The initial start-up procedure is described. The thermal transients resulting from scram tests are compared with the system analysis simulator studies. The instrumentation, control and stability of the reactor are evaluated. Steady state operating data are given.

S. G. Schaffer, "Testing Required for Full Power Operation at Shippingport Atomic Power Station."

Initial testing, either formal or informal, of the individual components and the various systems of a central electric generating station has always been common practice. The initial testing of the nation's first full scale atomic power station at Shippingport, Pennsylvania, differs somewhat from what has been common, principally in the formality and magnitude of the program. This paper presents a discussion of the periods of testing considered necessary to assure that the components and systems as designed will satisfy the functional requirements for the station and that they can be operated with no hazard to the safety of the personnel or equipment. The paper discusses three of these periods omitting the construction and limitation periods, the former since except for possibly more rigorous methods is little different from the construction of a conventional station and the latter, since it occurs after full power operation is beyond the scope of the paper. Additional periods of testing may be assigned following the currently designated ones as future experience indicates these to be necessary. Paper No. 83.

S. E. Beall and **R. W. Jurgensen,** "Direct Maintenance Practices for the Homogeneous Reactor Test."

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formed while the parts of the reactor are partially or completely submerged in water to reduce radiation levels. Tools with long handles permit the operator, standing above the equipment, to disconnect flanged joints, air lines, electrical and instrument leads, etc., in a minimum time. In this paper are described the techniques and tools employed to accomplish these various operations and to minimize intermixing of the contaminated process fluids with shielding water. Paper No. 82.

A. L. Medin and **R. J. Clark,** "Cleaning Nuclear Reactor Systems."

General cleaning requirements for nuclear reactor systems are reviewed. The authors discuss one of the major problems facing suppliers and purchasers of nuclear equipment—measurement of cleanliness. Paper No. 184.

H. D. Ongman, "Water Treatment Process for the Dresden Nuclear Power Station."

The heat cycle of the Dresden Nuclear Power Station utilizes a boiling water reactor operating on a dual cycle. Saturated steam at 950 psi and 500 psi is supplied to the turbine at separate admission points. The total flow of these two streams is about 2.6×10^6 lb per hr. Predicted system corrosion rates are given. Full flow condensate and bypass reactor water demineralization is used to remove corrosion products and other water impurities. A description of the secondary steam system chemical treatment is given. Paper No. 130.

Experimental Power Reactors

S. W. Flinn and **M. Petrick,** "Performance and Potential of Natural Circulation Boiling Reactors."

A limited parametric study of the potential and performance of natural circulation boiling nuclear reactors is presented on a preliminary basis. Analyses are based on engineering data and correlation extrapolations obtained from boiling studies at Argonne National Laboratory. Some interrelation-ships are shown of power, density, system pressure, average core coolant density, core height, riser height, channel hydraulic diameter, recirculation flow rate and exit steam void fraction. A brief discussion is given concerning certain interesting aspects of reactor design and their effects on performance. Performance curves of a promising reactor type are shown. Paper No. 98.

R. M. Fryar, "The Role of the Experimental Reactor in the Plutonium Recycle Program."

The objectives of the plutonium recycle program are discussed. It is concluded that certain technology is required for successful use of plutonium as a power reactor fuel. The program for ascertaining this information and the purpose, need and scope of an essential tool of the program, the experimental reactor, are developed in some detail. Paper No. 176.

D. Krucoff, "The Armour Dust Fueled Reactor (ADFR)."

A conceptual design study is being performed on the ADFR, a high temperature reactor useful for electric power production and as a source of chemical process heat. Paper No. 100.

L. Kornblith, Jr., S. Untermyer, L. Welsh and **W. H. Nutting,** "Vallecitos Boiling Water Reactor."

The Vallecitos Boiling Water Reactor which went critical on August 3 and delivered electrical power on October 20, 1957 is described. The plant produces 5000 kw of electricity but is capable of substantially higher thermal output. Delivery of the first 1,000,000 kwhrs was completed on December 20. The entire operation of the plant has been simpler and smoother than was expected. Results of the first few months of operation are discussed. Paper No. 213.

Instrumentation

L. C. Noyes, "Main Coolant Instrumentation for High Performance Pressurized Water Reactor Power Plants."

A brief résumé of the design requirements for pressurized water reactor temperature, pressure, flow and liquid level instrumentation is discussed. Paper No. 174.

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D. E. Collins, "Measurement of Primary Water Flow."

The paper discusses the problems encountered in flow meter application for a nuclear power plant. A Gentile Tube and Statham Laboratories, Inc. Differential Pressure Transducers were selected and the significance of calibration results and stability tests are covered in detail. Paper No. 6.

R. H. Morse and **R. N. Brey, Jr.,** "An Electronic Feedwater Control System for the Experimental Boiling Water Reactor."

The electronic feedwater control system (4 elements) for the EBWR is described. A general description of the installation is given with a block diagram of the control arrangement. Circuitry details are covered in simplified schematic diagrams of the control Unit, Bridge and Mixer. The versatility of this system as applied to a Research Project is described in detail. Paper No. 36.

R. N. Brey, Jr., "Control Systems for Boiling Water Power Reactors."

A control system for a typical single cycle Boiling Water Power Reactor is outlined. The Nuclear Safety and Feedwater Control systems are covered thoroughly. With comments on flux level control from steam flow and/or steam pressure using a bypass system, flux level control from generator demand is also described. Brief mention is made of the dual cycle type of Boiling Water Reactor and its control system. Paper No. 103.

F. C. Steiner, "A New Method for the Measurement of Gases in High Pressure Water Reactor Plants."

In water cooled reactor plants operating at pressures of about 2000 psi and temperatures in the range of 450 to 550 F hydrogen is added to the primary coolant. A simple and rapid method has been developed for measuring the concentration of total gases. Paper No. 34.

E. E. Lynch and **D. P. Waite,** "Steam Generator Instrumentation for a Nuclear Power Plant with Analog Computer Verification of Dynamic Action."

Pressurized water type reactors, used with smaller than conventional steam drums to convert from primary coolant heat to steam in a heat exchanger. The paper discusses "Swell" caused by steam bubbles raising the liquid level and presents a solution to the problem of feedwater control. Paper No. 163.

H. W. Bassett, Jr. and **E. R. Gasser,** "Control System on a Turbine-Generator Supplying Commercial Power as a By-Product of a Nuclear Test Reactor."

A simple steam control system which makes it possible to utilize the excess steam produced by a test nuclear power plant for the operation of a turbine-generator in conjunction with a steam dump condenser to produce commercial electric power.

The control system described incorporates features for safety and reliability combined with its basic function to allow for sudden changes in the steam flow demand to the turbine-generator without objectional system transients in the nuclear power plant. The method by which this is accomplished and the operational performance of the system is described herein. Paper No. 33.

V. S. Underkoffler and **R. G. Olson,** "Considerations in the Design of the Nuclear Safety Instrumentation System for the Enrico Fermi Atomic Power Plant."

The conceptual design of an instrumentation system for a central station nuclear power plant provides insight into the complexity of the instrumentation requirements for such a system. A proposed instrumentation system for a fast breeder power reactor is used as an illustration. Paper No. 42.

L. Kornblith, Jr., "Instrumentation for a Boiling Water Reactor."

The instrumentation of the General Electric Developmental Boiling Water Reactor supplying steam to a turbine operated by Pacific Gas and Electric Co. as part of their generating facilities. An attempt has been made in the design of the plant to keep the instrumentation as simple as possible consistent with safety, operability and the requirements for developmental facilities. The discussion will include both the nuclear and steam sections Paper No. 32.

P. Bonnaure, "Instrumentation and Control of French Thermal Reactors."

The report describes circuits used for control of French reactors. It also outlines some experimental control circuitry developed for these reactors. Neutron detectors and control rod servomechanisms are discussed, as are the advantages of the systems employed and how they contribute to inherent safety in reactor operation. Paper No. 152.

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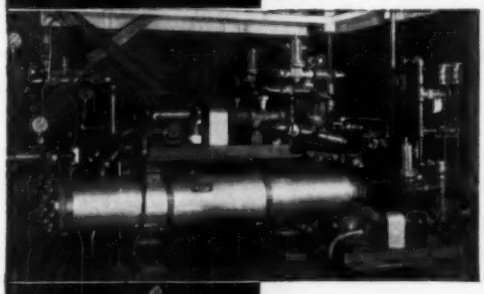

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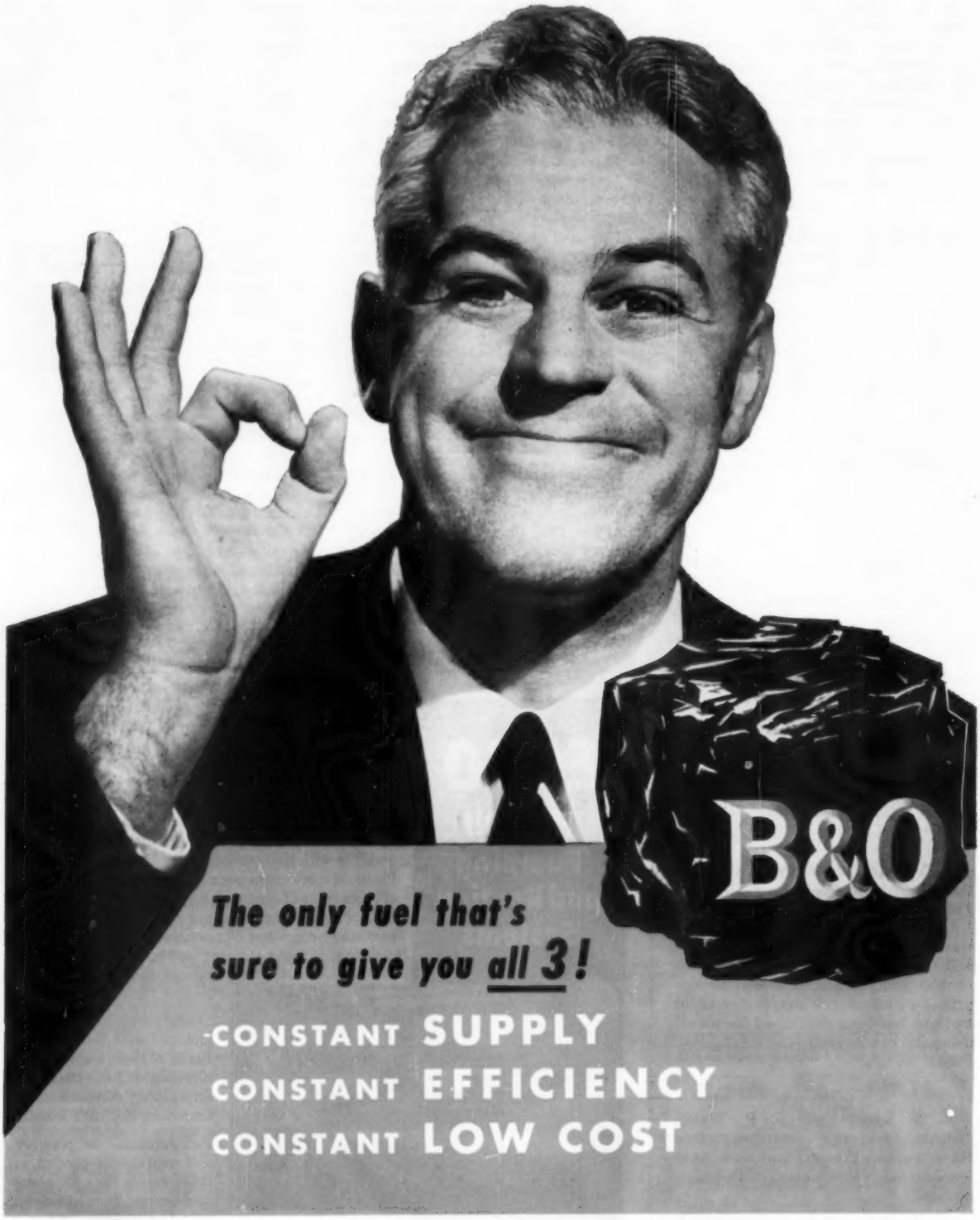

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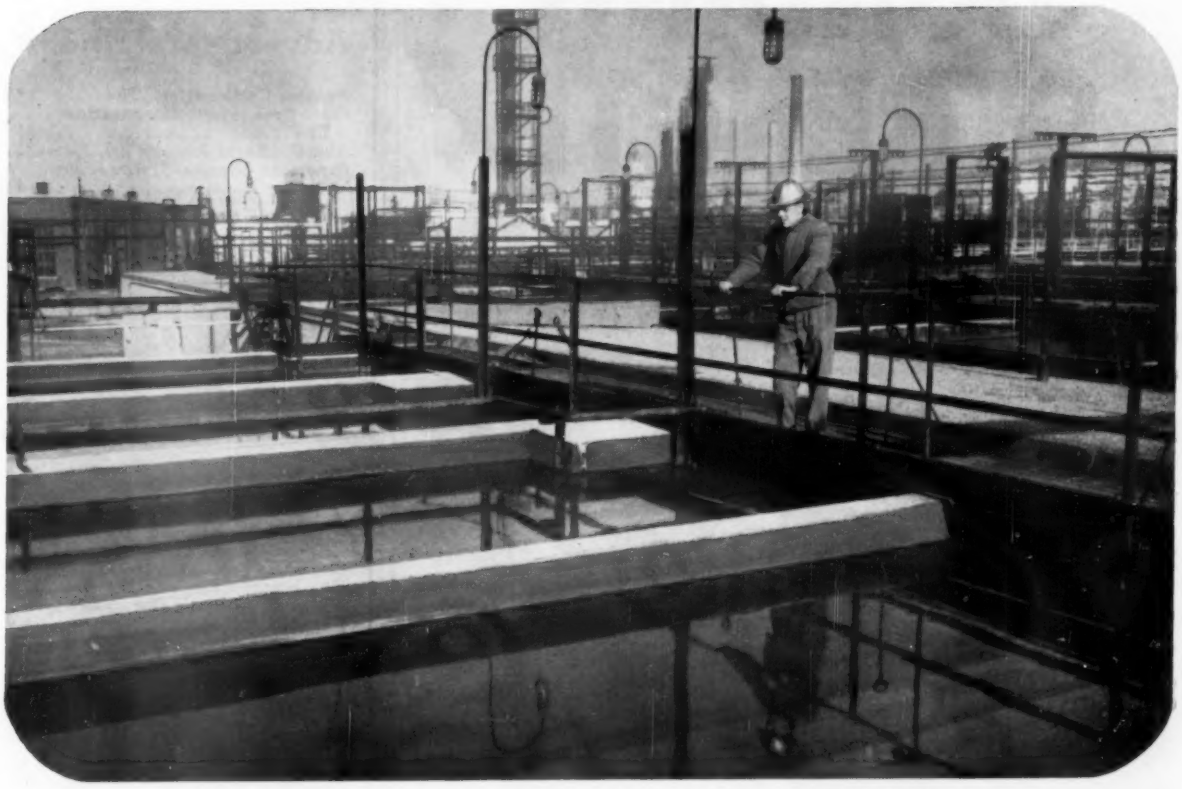

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Advertisers' Index

Aerotec Corporation, The..... *
Air Preheater Corporation, The..... 24
Alco Products, Inc..... 31
American-Standard, American Blower Division..... 4

Bailey Meter Company..... 8
Baltimore & Ohio Railroad.... 60
Bayer Company, The..... 28
Bituminous Coal Institute.... .....12 and 13
Blaw-Knox Co., Blaw-Knox Equipment Div..... *
Buell Engineering Company Inc..... 32

Cambridge Instrument Company..... *
Carborundum Company, The. *
Chesapeake & Ohio Railway... *
Clarage Fan Company..... *
Cochrane Corporation..... *
Combustion Engineering, Inc. .....Second Cover, 20 and 21
Combustion Publishing Company, Inc..... *
Copes-Vulcan Div., Blaw-Knox Company.....10 and 11
Crane Company..... *

Dampney Company, The..... 26
Dearborn Chemical Company. *
De Laval Steam Turbine Company..... 25
Diamond Power Specialty Corporation..16 and 17 Third Cover
Dowell Inc.....Fourth Cover

Eastern Gas & Fuel Associates 19
Economy Pumps, Inc..... *
Edward Valves, Inc..... *
Engineer Co., The..... 59

Fairmount Chemical Co., Inc. 57
Fly Ash Arrestor Corporation.. *

General Refractories Company *
Graver Water Conditioning Company..... *

Hagan Chemicals & Controls, Inc..... 9
Harbison-Walker Refractories Company..... *

Ingersoll-Rand Company..... 27

Johns-Manville..... *

(Continued on page 63)

M. W. Kellogg Company, The.. 22
Koppers Company, The..... *

Leeds & Northrup Company... 6

Manning, Maxwell & Moore, Inc..... 55
W. K. Mitchell & Company.... 29

National Aluminate Corporation..... *
Norfolk and Western Railway.. 14

Pacific Pumps, Inc..... *
Peabody Engineering Corporation..... *
Pennsylvania Crusher Div., Bath Iron Works Corp..... *
Pittsburgh Piping & Equipment Company..... 18
Powell Valves..... *
Prat-Daniel Corporation..... 40
Henry Pratt Company..... *

Refractory & Insulation Corporation..... 62
Reliance Gauge Column Company, The..... 63
Republic Flow Meters Company..... *
Republic Steel Corporation.... *
Research-Cottrell, Inc..... *
Richardson Scale Company... *
Rohm & Haas Company..... 61

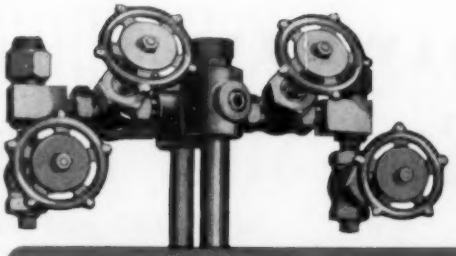
Stock Equipment Company... *
Sy-Co Corporation..... *

W. A. Taylor and Co..... 58
Todd Shipyards Corp., Products Div..... 57

Unafrax Construction Company..... 58

Walworth Company..... 64
Western Precipitation Corporation..... 2
Westinghouse Electric Corp.... 23
Westinghouse Electric Corp. Sturtevant Div.....7 and 30
C. H. Wheeler Mfg. Company..... *
Worthington Corporation..... 15

Yarnall-Waring Company..... 3
Yuba Consolidated Industries, Yuba Heat Transfer Div..... 5



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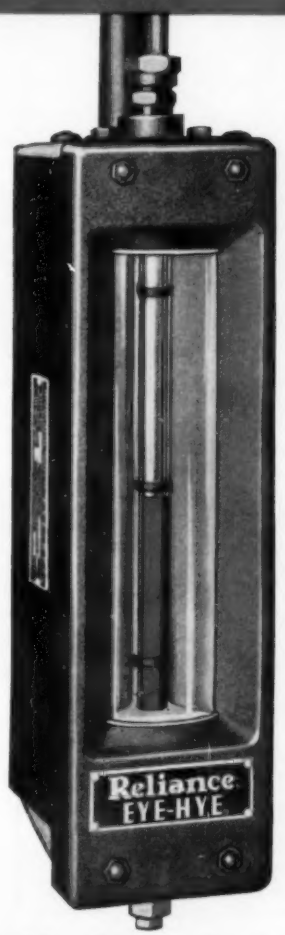

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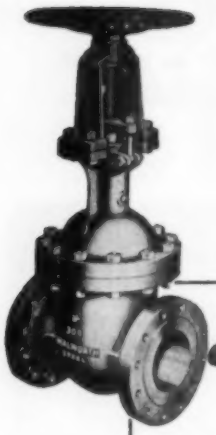

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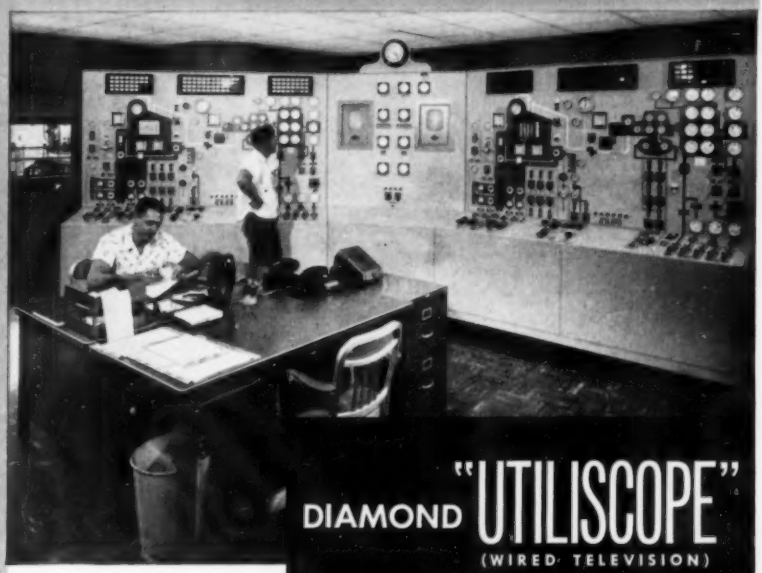

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